Preliminary Regulatory Impact Analysis

For

Safety Program for Surface Mobile Equipment

Proposed Rule

U.S. Department of Labor
Mine Safety and Health Administration
Office of Standards, Regulations, and Variances

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1. EXECUTIVE SUMMARY

Introduction

The Mine Safety and Health Administration (MSHA) is proposing to require that mine operators establish a written safety program for mobile and powered haulage equipment (excluding belt conveyors) at surface mines and surface areas of underground mines. The safety program would identify actions mine operators would take to identify risks to reduce hazards, accidents, injuries, and fatalities related to surface mobile equipment. The proposed rule would provide mine operators flexibility to develop a safety program that is appropriate for their mining operations. This rulemaking is one of several actions the Agency has taken to reduce accidents involving surface mobile equipment and improve miner safety and health.

Background

On June 26, 2018, MSHA published a request for information (RFI) (83 FR 29716) that focused on safety improvement technologies for reducing accidents involving mobile equipment at surface mines and surface areas of underground mines, and belt conveyors at surface and underground mines. The Agency held six stakeholder meetings and one webinar in August and September 2018. The meetings were held in Birmingham, Alabama; Dallas, Texas; Reno, Nevada; Beckley, West Virginia; Albany, New York; and Arlington, Virginia.

In the RFI, MSHA noted that "mobile equipment used at surface mines and surface areas of underground mines" is a broad category that includes bulldozers, front-end loaders, service trucks, skid steers, haul trucks, and many other types of vehicles and equipment. Accidents involving this equipment have historically accounted for a large number of fatalities. MSHA also reported that miners working near or around belt conveyors can become entangled in belt drives, belt rollers, and discharge points.

For the RFI, MSHA reviewed accident data from 2007 to 2017. During that period, 61 miners were killed in accidents involving mobile equipment. MSHA investigation of these accidents determined that contributing factors included: (1) no seat belt, seat belt not used, or inadequate seat belts; (2) larger vehicles striking smaller vehicles; and (3) equipment operators' difficulty in detecting the edges of highwalls or dump points, causing equipment to fall from substantial heights. Similarly, for accidents involving belt conveyors, MSHA reviewed the same 10-year period and determined that 17 fatalities were related to working near or around belt conveyors.

The RFI requested information from the mining community regarding the types of engineering controls available, how to implement such engineering controls, and how these controls could be used in mobile equipment and belt conveyors to reduce accidents, fatalities, and injuries. In particular, MSHA sought information and data on: (1) seat belt interlock systems or other controls that affect equipment operation when the seat belt is not properly fastened; (2) collision warning systems and collision avoidance systems that prevent accidents by decreasing equipment blind areas and reducing collisions; (3) technologies that would provide equipment operators better information regarding their location in relation to the edge of highwalls or dump points; (4) use of autonomous mobile equipment at surface mines; (5) technologies that provide additional protection from accidents related to working near or around belt conveyors; and (6) training and technical assistance that improves equipment operators' awareness of hazards at the mine site and ensures that miners lock and tag conveyor belts before performing maintenance work. MSHA received comments from mining associations, equipment manufacturers, mine operators, labor, the National Institute for Occupational Safety and Health (NIOSH), and the public.

One commenter observed that mine operators who develop and implement safety programs do so with the goal of preventing injuries, fatalities, and the suffering these events cause miners, their families, and their communities. For these mine operators, the commenter noted that preventing harm to their miners is more than just compliance with safety requirements; it reflects a culture of safety. According to this commenter, the culture of safety derives from a commitment to a systematic, effective, and comprehensive management of safety at mines with the full participation of the miners. Another commenter, a mining coalition, stated on the basis of its members' experiences that safety does best when mine operators develop and implement their own comprehensive safety programs.

A safety program includes a set of interrelated and interacting elements that are designed to establish and achieve (the same or similar) safety goals. Several types of organizations provide guidance on safety programs: (1) consensus standards organizations (e.g., the American Society of Safety Professionals (ASSP), Occupational Health and Safety Management Systems (ANSI/ASSP Z10-2012;(R2017) and the International Standards Organization (ISO), Occupational Health and Safety Management Systems – Requirements With Guidance for Use (ISO 45001:2018); (2) industry organizations (e.g., the National Mining Association (NMA), CORESafety®); and (3) government agencies (e.g., the Occupational Safety and health Administration (OSHA), Recommended Practices for Safety and Health Programs; and the Department of Transportation, 49 CFR part 270).

Most safety programs include a common set of elements that focus on identifying hazards in the workplace and developing a plan for preventing and controlling those hazards. Examples of common elements of a safety program include: (1) management commitment; (2) worker involvement; (3) hazard identification, prevention, and remediation, including workplace examinations for violations of mandatory safety and health standards; (4) miner training and education; and (5) program evaluation. MSHA believes that a safety program developed specifically to identify, prevent, and control hazards related to surface mobile equipment would reduce accidents, injuries, and fatalities while improving the overall safety culture of the mine.

Requirements of the Proposed Rule

This rulemaking targets hazards related to mobile and powered haulage equipment (excluding belt conveyors) used at surface mines and surface areas of underground mines. In developing the proposed rule, MSHA reviewed accident data from January 2003 to December 2018. During that period, there were 109 fatalities caused by hazards related to working near or operating surface mobile equipment in mines with 6 or more miners. MSHA believes that mine safety can be substantially improved when mine operators implement safety programs that produce a culture of safety, a more holistic approach to safety and health, and encourage technological solutions to prevent or mitigate hazards.

The proposed rule would require that operators with six or more miners establish and maintain a written safety program for surface mobile equipment used in surface mines and surface areas of underground mines. The rule would provide mine operators the flexibility to tailor the safety program to meet the specific needs of their operations and unique mining conditions.

Mine Sector Affected

The proposed rule would apply to surface mines and surface areas of underground mines, for mines with six or more miners. In total, 12,281 mines with 162,718 miners and 223,289 total employees are potentially in scope for the proposed rule. Of these, an estimated 5,027 mines with 142,969 miners and total employment of 192,637 have six or more miners each and would be directly covered by the rule.

Regulatory Alternative

MSHA considered requiring all mines, regardless of size, to develop and implement a written safety program for surface mobile equipment used at surface mines and surface areas of underground mines. Based on the Agency's experience and MSHA concluded that a mine operator with five or fewer miners would generally have a limited inventory of surface mobile equipment. These operators would also have less complex mining operations, with fewer mobile equipment hazards that would necessitate a written safety program. Thus, these mine operators are not required to have a written safety program, although MSHA would encourage operators with five or fewer miners to have safety programs.

Net Benefits

The proposed rule would have an annualized net benefit of $49.8 million at a 3 percent discount rate and $45.6 million at a 7 percent discount rate. Under the proposed rule, mine operators would be required to comply with the proposed requirements 6 months after publication of the final rule. MSHA believes that this would provide mine operators time to: develop and communicate the safety program to employees; evaluate mine operations for hazards; and eliminate and control identified hazards (e.g. engineering controls, work practices, and equipment maintenance). MSHA assumes that full annual benefits of the proposed rule would be achieved in the second year.

Executive Orders 12866 and 13563; Regulatory Flexibility Act

Executive Orders 12866 and 13563 require that agencies assess all costs and benefits of available regulatory alternatives and, if regulation is necessary, select regulatory approaches tailored to impose the least burden, consistent with regulatory objectives, and that benefits justify the costs (including potential economic, environmental, public health and safety effects, distributive impacts, and equity). Executive Order 13563 emphasizes the importance of quantifying both costs and benefits of reducing costs, harmonizing rules, and promoting flexibility.

Under E.O. 12866, a significant regulatory action is one that meets any of a number of specified conditions, including the following: having an annual effect on the economy of $100 million or more, creating a serious inconsistency or interfering with an action of another agency, materially altering the budgetary impact of entitlements or the rights of entitlement recipients, or raising novel legal or policy issues. The Office of Management and Budget (OMB) has determined that the proposed rule would be a significant regulatory action, though not an economically significant regulatory action, pursuant to section 3(f) of E.O. 12866.

Overall, the proposed rule is estimated have a 10-year total undiscounted net benefit of $530.8 million, based on a 10-year undiscounted benefit of $698.2 million and a 10-year undiscounted cost of $167.4 million. MSHA estimates the 10-year total discounted net benefits at 3 percent and 7 percent would be $437.5 million and $343.0 million, respectively. The estimated annualized net benefit at discount rates of 0 percent, 3 percent, and 7 percent would be $53.1 million, $49.8 million, and $45.6 million, respectively. The undiscounted, discounted and annualized net benefits estimates are based upon on the assumption that the proposed rule would be 80% effective in reducing the number fatalities and injuries involving miners and surface mobile equipment. In the net-benefits section, MSHA presents alternative net benefits estimates based upon differing levels of safety program effectiveness.

The Regulatory Flexibility Act (RFA), as amended by the Small Business Regulatory Enforcement Fairness Act (SBREFA), requires regulatory agencies to consider a rule's economic impact on both private and public small entities. For the mining industry, the Small Business Administration (SBA) defines a small business by NAICS code as shown in Table 6-1. MSHA has reviewed the proposed rule to assess and take appropriate account of its potential impact on small businesses, small governmental jurisdictions, and small organizations. Based on its impact analysis, MSHA believes that this proposed rule would not have a significant economic impact on a substantial number of small entities. The small entity impact analysis found estimated annual revenues for small mines of $53.856 billion, while the costs associated with the proposed rule were estimated at $38.77 million, or 0.07 percent of revenues.

2. INDUSTRY PROFILE

Introduction

This chapter provides information concerning the structure and economic characteristics of the underground coal mining industry, including the number of mines and employees by mine size. This data comes from the U.S. Department of Labor, Mine Safety and Health Administration, Educational Policy and Development and Program Evaluation and Information Resources.

Structure of the Mining Industry

MSHA divides the mining industry into two major sectors based on commodity: (1) coal mines and (2) metal and nonmetal mines. Each sector is further divided by type of operation (e.g., underground mines or surface mines). The Agency maintains data on the number of mines and on mining employment by mine type and size.

The proposed rule would apply to surface mines and surface areas of underground mines, for mines with at least six miners. MSHA estimates that in 2018, surface mines and mines with surface areas totaled 12,281 mines with 162,718 miners and 223,289 total employment. Of these, an estimated 7,254 mines with five or fewer miners would be exempt from the rule's requirements, leaving 5,027 in-scope mines. Of these, 584 are coal mines and 4,443 are metal/nonmetal (MNM) mines. See Table 2-1 for additional detail.

Table 2-1: Mines and Employment in 2018

Safety Program	Coal, MNM	Commodity	Number of mines	Total Miners	Total Employment
Mines with six or more miners	COAL		584	25,626	46,178
	MNM	Metal	163	29,377	38,778
		Nonmetal	488	18,988	24,936
		Sand and Gravel	1,494	19,662	22,584
		Stone	2,298	49,316	60,161
	MNM Total		4,443	117,343	146,459
Covered Subtotal			5,027	142,969	192,637
Mines with five or fewer miners	COAL		503	1,379	7,238
	MNM	Metal	102	302	793
		Nonmetal	352	954	1,218
		Sand and Gravel	4,459	11,626	14,515
		Stone	1,838	5,488	6,888
	MNM Total		6,751	18,370	23,414
Not Covered Subtotal			7,254	19,749	30,652
Grand Total			12,281	162,718	223,289

Source: MSHA MSIS Data (reported on MSHA Form 7000-2)

Table 2-2 below shows 2018, mining revenues were $109.4 billion and miners worked 415.1 million hours. MSHA estimates coal revenue at $27.2 billion, using production estimates multiplied by revenue per ton. For the MNM revenue figures, MSHA used the estimate of $82.2 billion from the U.S. Geological Survey's (USGS) annual commodity report.

Table 2-2: Mining Revenues and Miner Hours in 2018

	Estimated Revenue (billions)	**Miner Work Hours (millions)**
Coal mines	$27.2	120.3
MNM mines	$82.2	294.8
Total	$109.4	415.1

Source: MSHA MSIS Data (total hours worked at mines and coal production reported on MSHA Form 7000-2 at $35.99 per ton, https://www.eia.gov/coal/annual/archive/0584_2018.pdf, p. XVII). USGS reported 2018 MNM revenues at $82.2 billion. (U.S. Geological Survey, 2019, Mineral commodity summaries 2019: U.S. Geological Survey, 200 p., https://doi.org/10.3133/70202434)

3. COMPLIANCE COSTS

This and subsequent chapters present MSHA's estimates of costs and benefits associated with its proposed rule on Safety Program for Surface Mobile Equipment, along with its assumptions and methodology in detail. A summary of this preliminary regulatory impact analysis is included in the preamble of the notice of proposed rulemaking.

Introduction

This chapter presents MSHA's estimate of the cost that mine operators affected by the proposed rule would incur to develop the required safety program. The proposed rule would require surface mine operators and other operators with surface mine-related areas to establish a written safety program through which they would systematically evaluate risks to reduce accidents, injuries, and fatalities. The safety program would also mandate actions to: (1) identify new and existing safety strategies and technologies that would improve miners' safety and health and reduce fatalities and injuries; (2) maintain and repair surface mobile equipment; and (3) provide training on the mobile equipment safety program.

The quantified costs associated with this proposed rule would be: (1) costs associated with the development of the written safety program and (2) costs related to expenses that mine operators would incur to enhance safety and minimize risks.

Safety Program Development Cost

MSHA recognizes that mine operations are diverse, with varying mining methods, mine environments, types of mobile equipment, and mined commodities. Under this proposed rule, mine operators would be allowed to develop programs that are unique to their operations and/or build on existing programs.

Costs related to the written program are listed by particular actions required under this rulemaking. To develop the safety program, a mine operator would be required to implement various procedures and processes that identify hazards and manage risks. Many mine operators already have many of these procedures and processes in place. In such cases, operators would only have to identify and describe such procedures and processes to comply with this proposed rule. Therefore, MSHA's estimates of the average time it would take an operator to develop a written safety program reflect the fact that these operators would need to spend less time than others.

The hourly wage rate data used in MSHA's analysis assumes average rates for all mining and uses Bureau of Labor Statistics' 2018 Occupational Employment Survey (OES) mean wage rates adjusted for benefits and wage inflation since completion of the survey. All wage rates also include a 1% additional overhead factor. Costs are estimated using $65.10 as an average hourly supervisory rate, except for the item identified as clerical assistance, which uses a rate of $31.46 per hour. In addition, costs are estimated based on a projection that 5,027 mines would need to develop written plans. Table 3-1 summarizes the costs associated with a written safety program.

Table 3-1: Safety Program Development Costs

Major Safety Program Elements*	Mine Task Hours (Annual)	Total Hours (task hours x 5,027 mines)	Startup ($ millions)	Out-year Annual ($ millions)
Identifying hazards and manage risks	15	75,405	$4.9	$0.0
Evaluating technologies that enhance safety	60	301,620	$19.5	$0.0
Summarizing findings and developing written program	20	100,540	$6.5	$0.0
Clerical assistance to finalize program (clerical rate $31.03)	30	150,810	$4.7	$0.0
Reevaluating workplace activities due to changes in technology, conditions, processes, materials, or equipment; conducting on-site examinations; identifying hazards, trends, root causes, and taking corrective actions	20	100,540	$0.0	$6.5
Annual review and update of the safety program	5	25,135	$0.0	$1.6
Total including overhead of 1%			$35.7	$8.1

*The hourly rate including a 1% overhead used to estimate costs of clerical assistance to finalize programs is $32.46; the hourly rate including a 1% overhead used to estimate all other tasks is $65.10.

Overhead Costs

MSHA includes overhead costs in the form of a 1% increase in the wage rates associated with this analysis. The Agency requests comments on this assumption.

The mining environment generally involves very little overhead associated specifically with workers engaged in administrative or clerical tasks, and less still on those associated with mine health and safety. For many mines, office space is located on the mine site. The personnel engaged in the development and implementation of the written safety program required by this proposal would likely share such office space with personnel engaged in other clerical or administrative tasks unrelated to this proposal, such as bookkeeping, time and attendance tracking, etc.

MSHA believes that overhead costs not accounted for in the wages used here (including fringe benefits, etc.) for the personnel engaged in program development and implementation would be negligible. For this proposed rule, for which compliance will generally mean changes in work practices and other administrative controls (as opposed to building or changing infrastructure), the Agency uses 1% of wages for personnel engaged in program development and implementation as overhead costs.

MSHA seeks comments on including overhead costs in the labor costs for personnel developing and implementing a written safety program and on the estimate of the overhead costs in this analysis.

Safety Enhancement Cost

Under this proposed rule, MSHA would require mine operators to identify hazards, manage risks, and evaluate technologies that enhance safety. MSHA assumes that some mine operators would incur costs in implementing processes and controls because of this evaluation. These expenditures could range from low-cost and less advanced controls, such as signs and signals, to high-cost and more technologically advanced controls related to equipment modification, such as interlocked seatbelts or collision warning systems.

MSHA's recognizes the diverse nature of mining operations. Surface mine operations extract either coal or metal nonmetal mineral ore. There are five main types of surface mining methods used in extracting mineral ore: open pit mining, open cast mining, quarrying of dimension stones, highwall or auger mining, and dredging.

However, regardless of the mining method, most mining operations utilize a common set of mobile equipment to extract and remove mineral ore. For coal mining operations, the set of mobile equipment commonly utilized are ore-haulage trucks, excavators, loaders, conveyors, bulldozers, and utility trucks such as fuel and water trucks. For metal nonmetal mining operations, the set of mobile equipment commonly utilized is the same as for coal mining operations, but these operations also use forklifts and bobcats. For the proposed rule, MSHA excluded accidents involving conveyors; thus, MSHA did not estimate the number of conveyors utilized in both coal and metal nonmetal mining operations.

Experts at MSHA, with a wide range of mining experience, developed the following equipment estimates. At a coal surface mine, the number of pieces of mobile equipment found within a set of equipment range from a minimum set comprised of 2 ore-haulage trucks, 1 excavator, 1 loader, 2 bulldozers, and 1 utility truck to a maximum set comprised of 103 ore-haulage trucks, 31 excavators, 9 loaders, 49 bulldozers, and 10 utility trucks. At a metal nonmetal surface mine, the number of pieces of mobile equipment found within a set of equipment range from a minimum set comprised of 2 ore-haulage trucks, 2 loaders, 1 bulldozer, and 1 utility truck to a maximum set comprised of 60 ore-haulage trucks, 10 excavators, 10 loaders, 10 bulldozers, 50 utility trucks, and 50 forklifts.

In estimating the total number of mobile equipment pieces that exist industrywide at both coal and metal nonmetal surface mines, MSHA constrained the estimate so that the number of miners working in a pit or quarry area had to be greater than the estimated number of pieces of equipment that a mine uses in its operation. The estimation also assumed that a miner could be a mobile equipment operator. MSHA used the number of miners that worked at a mine's pit or quarry area along with the range in sizes of mobile equipment sets to develop a model that estimated the total number of mobile equipment pieces in operation, industrywide. MSHA estimated that, industrywide, coal and metal nonmetal mines and surface areas of underground mines utilize approximately 60,000 pieces of equipment to mine mineral ores.

Furthermore, MSHA additionally constrained the estimate by excluding mobile equipment found at mines with five or fewer employees and where the controllers of those mines oversee operations at only one mine. Based upon the constraint, MSHA estimated that the proposed rule would apply to 5,027 mines that utilize 41,994 pieces of mobile equipment. As a percentage, the mines covered by this proposed rule utilize 70 percent of the total industrywide count of 60,000 pieces of mobile equipment. On average, each surface mine the proposed rule would cover utilizes nine pieces of mobile equipment in its mining operations.

The safety-enhancing expenditures would vary widely across mine operations. Some operators would incur lower costs as they use less advanced controls such as signs and signals, while others would invest in higher-priced controls such as interlocked seatbelts or collision warning systems. Given this variation, MSHA assumes $500 per piece of surface mobile equipment as an average cost accounting for new technology purchases and existing technology repairs and modifications in the first year. From the second year on, the analysis assumes an average cost of $100 per piece of surface mobile equipment, accounted mostly for modification of existing technologies. The analysis assumes little incremental cost for repairs in the second year and beyond, because the repairs are already required by other MSHA standards.

MSHA estimates no incremental training costs, because this proposed rule requires no new or additional training. Training costs are already accounted for in training required by existing standards in 30 CFR parts 46, 48, and 77, which address mine hazard awareness and safety measures. MSHA invites commenters' views and estimates on training costs.

Using this average cost estimate, the proposed rule could require mine operators to incur safety improvement costs of approximately $21.0 million in the first year. Starting in the second year, MSHA assumes out-year costs of $4.2 million annually.

Compliance Cost Totals and Summary

MSHA estimates that the sum of the costs for the written program development plus the costs for safety enhancement would be $56.7 million in the first year and $12.3 million annually in the out-years starting from the second year of implementation (Table 3-2).

Table 3-2: Compliance Cost Summary

	Millions of Dollars (Undiscounted)	
Cost Item	Startup Costs	Annual Out-year Costs
Safety program development (inclusive of overhead costs)	$35.7	$8.1
Safety enhancement	$21.0	$4.2
Total Costs	$56.7	$12.3

Discounting

Discounting is a technique used to apply the economic concept that preferences are such that the value of money decreases over time. In this analysis, MSHA provides cost totals discounted at 0, 3, and 7 percent discount rates. The 0 percent discount rate is referred to as the undiscounted rate. MSHA used the Excel NPV function to determine the present value of costs and computed an annualized cost from the present value using the Excel PMT function.[1] This function has a number of financial uses, and the function returns a negative number. The result was multiplied by -1 to obtain the annualized costs in positive numbers which are subtracted from benefits to obtain the net difference. MSHA used the PMT function to provide the annualized[2] cost over 10 years at 3 and 7 percent discount rates after summing costs.

Summary of 10-Year Compliance Costs

MSHA estimates that the total undiscounted cost of the final rule over a 10-year period will be approximately $167.44 million, and the present-value cost will be $148.0 million at a 3 percent discount rate and $127.9 million at a 7 percent discount rate. (See 3-3.) The total cost annualized over 10 years will be approximately $16.7 million per year (undiscounted), $16.8 million at a 3 percent rate, and $17.0 million per year at a 7 percent rate. The calculations use additional decimals than shown in the display below, which affects totals and independent rounding.

Table 3-3: Summary of 10-Year Compliance Costs By Year

Year	Safety Program Development ($ millions)	Safety Enhancement ($ millions)	Yearly Total (undiscounted) ($ millions)
1	35.8	21.0	56.8
2	8.1	4.2	12.3
3	8.1	4.2	12.3
4	8.1	4.2	12.3
5	8.1	4.2	12.3
6	8.1	4.2	12.3
7	8.1	4.2	12.3
8	8.1	4.2	12.3
9	8.1	4.2	12.3
10	8.1	4.2	12.3
10-Year Total Undiscounted			$167.4
Annualized Undiscounted			$16.7

[1] Office of Information and Regulatory Affairs, Regulatory Impact Analysis: Frequently Asked Questions, February 7, 2011

[2] Annualized values use the end of period option with no future value in the PMT function.

10-Year Total at 3 Percent Discount Rate	$148.0
Annualized at 3 Percent Discount Rate	$16.8
10-Year Total at 7 Percent Discount Rate	$127.9
Annualized at 7 Percent Discount Rate	$17.0

4. BENEFITS

Introduction

MSHA believes that the proposed rule would significantly improve miners' safety. The proposed rule would apply to mine operators of surface mines and surface areas of underground mines with six or more miners. These mine operators would be required to establish and maintain a written safety program that would include actions the operator would take to identify risks and eliminate or mitigate those risks related to the movement and operation of surface mobile equipment. The safety program would also include actions the operator would take to: evaluate technologies that enhance safety; maintain and repair surface mobile equipment; and train on the mobile equipment safety program for all miners.

The proposed safety program could create benefits through several mechanisms. First, the proposed safety program would include all actions an operator would take to evaluate risks to eliminate or mitigate hazards to reduce accidents, injuries, and fatalities. Second, MSHA believes the process of developing and maintaining a safety program would lead to a safety culture at the mine. A safety culture consists of shared beliefs, practices, and attitudes about safety. MSHA believes that a safety culture would also develop as mine management and miners work together to identify hazards and determine appropriate controls to prevent or mitigate those hazards. In addition, MSHA believes that through the collaborative focus on safety by operators and miners, there will be additional unquantifiable financial benefits, such as reduced insurance premiums and decreased down time from accidents.

MSHA is aware that some mine operators that have developed safety programs based on OSHA-recommended practices, or consensus standards, would already have procedures in place to continually identify workplace hazards and evaluate risks. MSHA believes that mine operators with existing, effective safety programs would likely be required to make few, if any, adjustments to their programs to meet the requirements of the proposed rule. However, because of the difficulty in obtaining details about safety programs and any impact they may have on surface mobile equipment operations at these mines, MSHA did not remove any costs from its estimates.

This chapter includes the summary information from a series of more detailed trend analyses. The details of the model choices and outputs are included in the Technical Appendices.

Accident Data and Incidence Rates

The reporting and recordkeeping provisions in 30 CFR part 50 require mine operators to report each accident, injury, and illness to MSHA on Form 7000-1. The form shall be completed and mailed within 10 working days after an accident or occupational injury occurs or an occupational illness is diagnosed. Data collected through MSHA Form 7000-1 enables the Agency to detect accident and injury trends related to mining equipment, work locations, or tasks. Data collected through Form 7000-1 includes, among other data elements, a description of the conditions contributing to the accident or injury, the equipment involved in the accident, if the injury resulted in death or resulted in permanent disability, number of days away from work, and number of days of restricted work.

MSHA's Mine Injury and Worktime Quarterly Report summarizes data reported through Form 7000-1 and classifies reported injuries into three categories:

1. FATAL: Occurrences resulting in death.
2. NFDL: Nonfatal occurrences with Days Lost (lost workdays). That is, nonfatal injury occurrences that result in days away from work or days of restricted work activity.
3. NDL: Occurrences with No Days Lost. That is, nonfatal injury occurrences resulting only in loss of consciousness or medical treatment other than first aid, but not in any lost workdays.[3]

MSHA reviewed the accident data collected through MSHA Form 7000-1 and identified 1,652 accidents from 2003 to 2018 that involved surface mobile equipment at mines with six or more miners. For this analysis, MSHA did not include accidents that occurred at mines with five or fewer.

Incidence rates can be used to show the relative rate of injuries. An incidence rate for injuries is computed from the following formula: ((Injury Occurrences * 200,000 hours) ÷ Employee hours worked). The 200,000 hours variable represents 100 employees working 40 hours per week, 50 weeks per year, and provides the standard base for calculating an incidence rate for an entire year.

MSHA developed incidence estimates for coal and MNM mines. As in the Compliance Costs chapter, summary information is provided in this chapter. Detailed model information showing workhours, incidence rates, and the relationships are provided in the Technical Appendices. The injury and fatality trend data include decimal values to best estimate the overall trend. MSHA is not implying that a partial injury or fatality is possible. Rather, MSHA maintains the decimal values for monetization that matches the trend as well as the trending methodologies assume continuous data that represent all possible dates and times within a year. The final summary of injuries and fatalities are presented in whole numbers although the monetization is calculated with the full precision decimal values.

MSHA is proposing that mine operators establish and maintain a written safety program 6 months after publication of the final rule. Providing the 6-month compliance period would delay the time when benefits are fully realized. However, MSHA believes that during the first year as mine operators begin the process of developing their safety program some benefits would be realized. In the first year, MSHA assumes 10 percent of a full-year reduction in injuries and fatalities would be realized. In year two, full benefits of the proposed rule would be achieved.

Baseline Accident and Incident Data

Table 4-1, shows the historical data and future trend forecast for fatalities and NFDL and NDL incidents for coal, and metal/nonmetal mines. MSHA has included the details of the trend methodology for the baseline in the appendices.

[3] Minor injuries requiring only first aid are not reportable.

Table 4-1: Fatalities and Injuries Involving Surface Mobile Equipment at Coal Mines and Metal Nonmetal Mines with 6 or More Miners

(Historical actual for 2003-2018 and trend forecast for 2019 -2029)

Year	Coal			MNM			Total		
	Fatalities	NFDL	NDL	Fatalities	NFDL	NDL	Fatalities	NFDL	NDL
2003	6	24	7	1	46	21	7	70	28
2004	4	35	15	2	59	29	6	94	44
2005	5	33	25	6	55	25	11	88	50
2006	2	42	13	5	62	38	7	104	51
2007	4	32	12	4	44	27	8	76	39
2008	4	30	17	2	70	23	6	100	40
2009	5	36	15	4	30	15	9	66	30
2010	3	30	10	3	46	13	6	76	23
2011	2	36	10	1	26	12	3	62	22
2012	2	19	7	4	36	8	6	55	15
2013	1	16	5	4	34	13	5	50	18
2014	3	15	15	6	38	16	9	53	31
2015	2	16	5	3	26	19	5	42	24
2016	0	11	2	5	29	16	5	40	18
2017	4	18	5	6	28	14	10	46	19
2018	0	20	6	6	29	14	6	49	20
2019	1	19	4	5	25	15	6	44	19
2020	1	17	4	5	23	15	6	40	19
2021	1	16	3	5	21	15	6	37	18
2022	1	16	3	5	18	15	6	34	18

2023	1	16	3	5	16	14	6	32	17
2024	1	16	3	5	14	14	6	30	17
2025	1	16	3	5	12	14	6	28	17
2026	1	16	2	5	9	14	6	25	16
2027	1	16	2	5	7	14	6	23	16
2028	1	16	2	5	5	14	6	21	16
2029	1	16	2	5	3	14	6	19	16

MSHA assumes that the proposal could reduce the projected fatalities and injuries by 80 percent, starting from the second year of the implementation. For the first year, the Agency assumes that only 10 percent of the full-year reduction will be achieved, as mine operators may not yet have fully implemented their written safety programs. MSHA solicits comments on this assumption. Table 4-2 displays the projected reduction in fatalities and non-fatal injuries over a 10-year period.

Table 4-2: Projected Reduction in Fatalities and Non-fatal Injuries at All Mines with 6 or More Miners

Year	Fatalities	NFDL	NDL
1*	0.48	3.52	1.52
2	4.80	32.00	15.20
3	4.80	29.60	14.40
4	4.80	27.20	14.40
5	4.80	25.60	13.60
6	4.80	24.00	13.60
7	4.80	22.40	13.60
8	4.80	20.00	12.80
9	4.80	18.40	12.80
10	4.80	16.80	12.80

* MSHA assumes that due to timing of implementation, the startup will result in only 10% of likely reduction of the overall as the operators begin implementing their programs.

Sensitivity Analysis

MSHA reviewed several studies on the effectiveness[4,5] of safety programs in reducing occupational fatalities and non-fatal injuries under two scenarios. One scenario assumes the proposed program would reduce fatalities and non-fatal injuries by 20 percent, whereas the other scenario assumes safety program effectiveness rate of 50%. Table 4-3 presents projected reductions in fatalities and injuries from the Proposed Rules based on effectiveness rates of 20% and 50%.

Table 4-3: Projected Reductions at an Effectiveness Rate of 20%, 50%, and 80%

	Program effectiveness at 20%			Program effectiveness at 50%			Projected Reduction (Program effectiveness at 80%)		
Year	Fatalities	NFDL	NDL	Fatalities	NFDL	NDL	Fatalities	NFDL	NDL
1*	0.11	1.00	0.44	0.30	2.20	1.00	0.48	3.52	1.52
2	1.22	8.00	3.89	3.00	20.00	9.50	4.80	32.00	15.20
3	1.22	7.44	3.67	3.00	18.50	9.00	4.80	29.60	14.40
4	1.22	6.89	3.67	3.00	17.00	9.00	4.80	27.20	14.40
5	1.22	6.44	3.44	3.00	16.00	8.50	4.80	25.60	13.60
6	1.22	6.00	3.44	3.00	15.00	8.50	4.80	24.00	13.60
7	1.22	5.67	3.44	3.00	14.00	8.50	4.80	22.40	13.60
8	1.22	5.00	3.22	3.00	12.50	8.00	4.80	20.00	12.80
9	1.22	4.60	3.22	3.00	11.50	8.00	4.80	18.40	12.80
10	1.22	4.22	3.22	3.00	10.50	8.00	4.80	16.80	12.80

* MSHA assumes that for the first year, only 10% of the full-year projected reduction would be achieved as the mine operators begin implementing their programs.

MSHA believes that full implementation of this proposed rule will most likely result in an 80% reduction in fatalities and non-fatal injuries, for several reasons. First, the performance-oriented structure of the proposal allows and would require mine operators to tailor their safety programs for surface mobile equipment to the specific equipment and conditions at their mines. Mine operators are generally well-positioned to gauge the effectiveness of specific safety measures and implementation methods and would consider mine-specific knowledge and experience when

[4] LaTournette, Tom and Mendeloff, John, *Mandatory Workplace Safety and Health Programs – Implementation, Effectiveness, and Benefit-Cost Trade-Offs (2008),* Rand Institute for Civil Justice Center for Health and Safety in the Workplace, www.rand.org

[5] OSHA, *Recommended Practices for Safety and Health Programs,* October 2016, www.osha.gov.

developing and implementing the safety program described in this proposal to target areas of greatest concern.

In addition, MSHA intends to promote effective compliance by providing guidance and outreach about compliance requirements and effective safety programs, through the Agency's Educational Field and Small Mine Services division and more generally through its website and other interactions with stakeholders such as MSHA's quarterly stakeholder calls. The Agency further plans to provide sample programs on which mine operators can base their mine-specific programs. Furthermore, the Agency will continue to emphasize powered haulage and mobile equipment safety through MSHA enforcement personnel and their inspections of mines. MSHA's previous special initiatives have, in the Agency's experience, resulted in increased effective compliance and reduced injuries and fatalities through heightened enforcement and increased outreach, during enforcement inspections, regarding effective compliance strategies.

MSHA believes that the proposed rule permitting mine operators to choose and effectively implement safety controls tailored to their specific mines, together with planned compliance assistance and enforcement support, would result in a comparatively high reduction in fatalities and non-fatal injuries. The Agency, thus, expects that the proposed rule would result in an 80 percent reduction in fatalities and non-fatal injuries. MSHA requests comment on this assumption.

Benefit Monetization

As it has done in previous regulations, MSHA uses the measure of risk reduction as applied to fatalities that is known as the Value of a Statistical Life (VSL). VSL is not the valuation of life, but the valuation of reductions in risks. A wide range of federal agencies use the VSL concept in rulemaking, and it is the preferred approach recommended in OMB Circular A-4, which governs regulatory analysis. To estimate the monetary values of the reductions in fatalities, VSL represents an analysis that relies on the theory of compensating wage differentials (i.e., the wage premiums paid to workers to accept the risk associated with various jobs) in the labor market. A correlation observed between higher job risk and higher wages suggests that employees demand monetary compensation in return for incurring greater risk. For low-probability risks, economists assume that the willingness to pay to avoid the risk of a fatal injury increases proportionately with growing risk. The earliest methods of estimating used wage studies and survey research to estimate the average value for very small changes in risk, and then scaled the estimate to one. For example, when an individual is willing to accept additional pay of $10 for an additional risk of death of one in a million, the estimated VSL is approximately $10 million (i.e., $10 per individual x 1 million individuals). Newer studies by a variety of researchers, discussed below, use raw data, analyses, and information from the Census Bureau household survey, the Bureau of Labor Statistics Census of Fatal Occupational Injuries (CFOI), and the University of Michigan's Panel Study of Income Dynamics (PSID). This benefit analysis covers a range of research on VSL.

Estimating the Value of Fatalities and Injuries Prevented

In previous rules before the CFOI research became available, MSHA estimated the value of deaths and injuries prevented based on a 2003 meta-analysis by Viscusi & Aldy adjusted for inflation. Viscusi and Aldy (2003) analyzed several studies that used a willingness-to-pay methodology to estimate the imputed value of life-saving programs. This meta-analysis found that each fatality prevented was valued at approximately $7 million and each lost-time/non-fatal injury was valued at approximately $50,000 in 2000 dollars.[6] The $50,000 value equals 0.7 percent of the VSL.[7] Their VSL estimate, while within the range of the substantial majority of such estimates in the literature, is lower than estimates in more recent research papers and lower than recent estimates used by other federal agencies such as the Department of Transportation (DOT) and United States Coast Guard.[8]

Non-fatal injuries are far more common than fatalities and vary widely in severity, as well as probability. The resulting loss in quality of life includes pain and suffering and reduced income. While estimates of willingness-to-pay to avoid injury are available, these estimates are generally only available for an average injury resulting in a lost workday, not for a range of injuries varying in severity. Because detailed willingness-to-pay estimates covering the entire range of potential disabilities are unobtainable, when the number of injuries is small enough to analyze and categorize, MSHA has traditionally developed estimates for two classes of non-fatal injuries: lost-time injuries and permanent disabling injuries. For this rule, the list of incidents is quite lengthy, and the data systems do not provide sufficient information to categorize by injury severity. For this proposed rule, MSHA has therefore analyzed incident rates separated into fatal, NFDL, and NDL.

Selection of A VSL

For this proposed rule, MSHA considered a number of different sources and methods for selecting an appropriate VSL. DOT, for instance, assigns a dollar value to prevented fatal injuries. To come up with that value, DOT relied on recent studies that considered risk and pay in various occupations. In DOT's 2012 guidance, entitled "Treatment of the Economic Value of a Statistical Life," the agency reviewed nine studies that considered risk and pay in various occupations, arriving at $9.1 million as the value of statistical life at that time.

The most-cited body of research applicable to this rulemaking is comprised of hedonic wage studies that estimate the wage differential that employers must pay workers to accept riskier jobs after considering other factors. "As originally described by Jones-Lee (1974), Thaler and Rosen (1976), and Smith (1979), the theory relies on compensating wage differentials; consequently, estimating these wage-risk premia requires measures of the relative riskiness of the various jobs

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[6] Although many analysts refer to the text in the body of the paper that says "approximately $7 million," the appendix to their article shows the details and the base value for adjustment is $6.7 million.

[7] The 0.7 percent is rounded for display purposes. The actual value can be found by calculating $50,000/$6.7 million.

[8] Before issuing their 2013 updated guidance, DOT convened a panel of experts to review current VSL research. The panel unanimously concluded that hedonic wage studies completed within the previous 10 years using the CFOI database are the most appropriate. At that time, DOT updated their VSL guidance to $9.1 million (2012 dollars). The most recent DOT update, dated August 18, 2016, updated the VSL value for a 2015 base year to $9.6 million. See https://www.transportation.gov/sites/dot.gov/files/docs/2016%20Revised%20Value%20of%20a%20Statistical%20Life%20Guidance.pdf. DOT's guidance also includes formulas for updating by year.

. . . ."[9] Even before newer data sources and methods allowed researchers to look at different populations reliably, researchers were addressing the issue of whether a single number was representative or if population factors affected VSL as the fundamental theory suggests.[10] In 2010, Viscusi concluded, "To the extent that there are segmented labor markets in which people face different labor market opportunities, there will be differences across the population in their estimated VSL."[11] In a recent paper, Kniesner and Viscusi state, "One must be careful to remember that the proper comparison here is within an industry and occupation across workplaces." [12] These articles address both the analytical issue regarding the representativeness of a single number and the population that the VSL represents, as both issues are core to the concept and calculation of any VSL number.

Besides the problem of identifying and quantifying these factors, researchers must have a reliable source of data on fatality and injury risks and assume that workers' psychological risk assessment conforms to the objective data. The accuracy of hedonic wage studies has improved over the last decade with the availability of more complete data from the CFOI, supported by advances in econometric modeling, including the use of panel data (from the PSID). DOT notes that recent studies have used panel data to analyze the behavior of workers who switch from one job to another where the analysis can safely assume that any trade-off between wage levels and risk reflects the preferences of a single individual, and not differences in preferences among individuals, which provides more reliable results than older studies.[13] Kniesner and Viscusi concluded that, "The most reliable U.S. estimates are those based on the CFOI data . . . ."[14] In addition, advances in data and econometric techniques have allowed specialized estimates of VSL for particular subgroups, such as workers in particular industries. "A principal characteristic that drives differences in estimates of VSL is the level of individual income." Viscusi's 2013 article[15] emphasizes that, when possible, labor characteristics should be used to develop VSLs. Viscusi presents a table of four VSLs estimated using two functional forms and two fatality rates based on hours and employment. The article states that the narrow and overlapping confidence intervals from the different approaches indicate that the VSL estimates are relatively stable

[9] Scotton, Carol R., *New risk rates, inter-industry differentials and the magnitude of VSL estimates*, Journal of Benefit-Cost Analysis , Volume 4 , Issue 1 , 28 March 2013, DOI: https://doi.org/10.1515/jbca-2012-0015, pp 40-41.

[10] The economic issue is whether the populations demonstrate heterogeneity or homogeneity. Several of many articles are referenced in this discussion.

[11] W. Kip Viscusi, *Policy Challenges of the Heterogeneity of the Value of Statistical Life*, 6 Foundations and Trends in Microeconomics. 99 (2010), Available at: https://scholarship.law.vanderbilt.edu/faculty-publications/95, p 102.

[12] Kniesner, Thomas J. and Viscusi, W. Kip, *The Value of a Statistical Life* (April 10, 2019). Forthcoming, Oxford Research Encyclopedia of Economics and Finance, Vanderbilt Law Research Paper No. 19-15, Available at SSRN: https://ssrn.com/abstract=3379967 or http://dx.doi.org/10.2139/ssrn.3379967.

[13] For this reason, as was noted above, the expert panel convened by DOT in 2012 recommended that only studies conducted during the last decade be used.

[14] Kniesner and Viscusi, *The Value of a Statistical Life*, p. 8.

[15] Viscusi, W. Kip, *Estimating the Value of a Statistical Life Using Census of Fatal Occupational Injuries (CFOI) Data*, (July 9, 2013). Vanderbilt Law and Economics Research Paper No. 13-17.

whether the hours-based fatality rate or employment-based measure is used. The article shows the one of the highest fatality rates is for mining.[16]

Even newer research continues to show much higher VSL values with better statistical support. A comprehensive look at the VSL history and a study using the CFOI data and regression analysis of past meta studies concluded, “After correcting for publication selection bias, the estimated VSL range is from $9.1 million to $13.7 million based on the VSL equations.” [17] The same article identifies a publication selection bias in past studies with an identified underrepresentation of VSL. Using regression analysis and the CFOI, studies exhibit a substantial premium ranging from $2.5 million to $4.2 million (p.47) over previous studies. The article provides considerable information on the distribution of VSL studies using the CFOI data ranging from $5.0 million to $28.6 million. The median value reported was $11.3 million with a mean of $14.0 million. Even newer reviews of the research conclude that estimates have been improving in terms of statistical bias, econometric methods, and reliability of estimates. Kniesner and Viscusi’s 2019 article concluded that the CFOI data studies are the most reliable and have the least measurement error, and that the mean estimate from recent studies is $13.1 million.

Research by Viscusi and Aldy (2003)[18] estimated the elasticity of VSL with respect to increases in real income to be between 0.5 and 0.6. However, research by Kniesner, Viscusi, and Kiliak (2010)[19] examined elasticity across income quantiles. Based on a liner regression of VSL on the quantile-specific real family income, the overall income elasticity of VSL across the quantiles was 1.44. In contrast to this, research by Viscusi and Masterman (2017)[20] found the income elasticity of the VSL for the United States to be between 0.5 and 0.7. Taking all these studies listed together, MSHA has concluded that 1.0 is the most appropriate primary estimate for the

[16]Viscusi’s 2013 article is the first research MSHA is aware of that touches upon the high risk of mining (Table 1) and VSL. Mining is identified as having substantial risk and the discussion of the new VSL values emphasize risk, whether by industry or occupation. The article includes calculation with the hours based fatality rates and the employment based fatality rate. Using industry specific values is consistent with the guidance of OMB Circular A-4, “The valuation of fatality risk reduction is an evolving area in both results and methodology. Hence, you should utilize valuation methods that you consider appropriate for the regulatory circumstances. Since the literature-based VSL estimates may not be entirely appropriate for the risk being evaluated (e.g., the use of occupational risk premia to value reductions in risks from environmental hazards), you should explain your selection of estimates and any adjustments of the estimates to reflect the nature of the risk being evaluated.” (p. 31)

[17]Viscusi, W. Kip, “The Role of Publication Selection Bias in Estimates of the Value of a Statistical Life," American Journal of Health Economics, Vol. 1, No. 1 (Winter 2015), pp. 27-52. The study uses a base year of 2013 for dollar comparisons.

[18] Viscusi, W.K, and J.E., Aldy (2003) “The Value of Statistical Life: A Critical Review of Market Estimates Throughout the World.” *Journal of Risk and Uncertainty.* 27(1): 5-76

[19] Kniesner, T.J., W.K. Viscusi and J.P. Ziliak (2010). “Policy Relevant Heterogeneity in the Value of Statistical Life: New Evidence from Panel Data Quantile Regressions.” *Journal of Risk and Uncertainty.* 40(1): 15-31.

[20] Viscusi, W.K., and Clayton Masterman (2017). “Income Elasticities and Global Values of a Statistical Life.” *Journal of Benefit Cost Analysis.* 8(2): 226-250

income elasticity,[21] with 0.774 and 1.44, respectively, as the low- and high-value estimates. MSHA requests comments on these conclusions.

VSL Estimates

Table 4-4 shows MSHA's VSL assumptions and adjustments for the three possible VSL estimates that follow.

Benefit Estimate: For this proposed rule, MSHA used a 2018 base year primary estimate of $13.6 million, based on the OMB Circular A-4 2003 upper limit (adjusted to 2018 using the Implicit Price Deflator) and an income elasticity of 1.0, after considering:

1. The improvements in VSL estimates using the CFOI data, which show higher values than earlier meta-analyses of large numbers of studies and a higher mean value overall,
2. The use of the CFOI, PSID, and Census data, which allow estimations of VSL for specific populations[22] as the economic theory recommends, resulting in estimates higher than the maximum allowed by the A-4 guidance, and
3. The likelihood of significant publication bias in older studies[23].

The steps in adjusting the base are as follows:

1. Update base year VSL to base year 2018 using Implicit Price Deflator.
2. Convert the CBO forecast income growth to real income growth by dividing by the Gross Domestic Product (Implicit Price Deflator, Index 2012=100, Annual, Seasonally Adjusted) for each year in the future.
3. Adjust the real income growth by applying the income elasticity of 1.0 (factor from step 2 ^ income elasticity).

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[21] Researchers have estimated a wide range for the average income elasticity for VSL use. Older studies were primarily meta studies, while newer studies increasingly focus on wage studies. Newer research, which is confirming the theory that VSL increases with higher incomes, is producing a more narrow range and finding income elasticity values that exceed 1.0 consistent with the theory of VSL. It is worth noting, however, that a number of theoretical questions surrounding the income elasticity adjustment remain, such as whether discounting for both costs and benefits negates the need for an adjustment. MSHA has therefore concluded that 1.0 is an appropriate elasticity to use, as it is in the middle of the range of estimates and is also consistent with what some other agencies are using. For a broad description of the recent literature regarding income elasticity for VSL, see articles such as Hammit and Robinson (2011), Doucouliagos et al (2013), Viscusi (2013), Viscusi and Aldi (2003), and Viscusi (Summer 2015). Visusi's 2015 article. For information on examples of federal agencies using income elasticity to adjust VSL, see the EPA BenMap, EPA Particulate Matter rule evaluation (EPA-452/R-12-005, December 2012) and DOT citations in the reference list at the end of this evaluation.

[22] See Viscusi, "Estimating the Value of a Statistical Life Using Census of Fatal Occupational Injuries (CFOI) Data, and footnote 12.

[23] Viscusi, W. Kip, "The Role of Publication Selection Bias in Estimates of the Value of a Statistical Life," American Journal of Health Economics, Vol. 1, No. 1 (Winter 2015), pp. 27-52. The study uses a base year of 2013 for dollar comparisons.

4. Increase the base-year (2018) value of the VSL by the adjustment factor determined in steps 2 and 3 for each year after 2018. For the proposed rule, MSHA reviewed DOT's findings and used the Congressional Budget Office (CBO, 2020) forecast of 1.9 percent income growth each year, deflated by the Implicit Price Deflator, [24] for forecast years.

Low Benefit Estimate: MSHA's estimate of the lower value of VSL of $10.1 million (DOT Expert Panel) and an income elasticity of 0.775 is based upon the average of the income elasticity in Viscusi and Aldy (2003) and the 2015 DOT update [=(.55+1)/2]. This average income elasticity of 0.775 is close to the average (0.7) found in Hammitt and Robinson (2011). In year 10, the VSL would become $12.47 million under this low-benefit scenario.

High Benefit Estimate: MSHA's estimate of the upper value of $15.2 million is based on the same adjustment methodology as the primary estimate but with the higher base value. The average elasticity of 1.44 used is consistent with the findings in Kniesner, Viscusi, and Kiliak (2010).[25] In year 10, the VSL would increase $20.01 million under this high-benefit scenario.

Table 4-4: Annual Values for VSL, NFDL, and NDL*

Assumption or Value	Low-Benefit Case	Middle-Benefit Case (Used in the Analysis)	High-Benefit Case
Study or Source	DOT Expert Panel	OMB A-4 Upper Bound	Viscusi CFOI Upper Bound estimate (mining)
Study year	2012	2003	2013
VSL Study Year $	$9.1 million	$10 million	$14 million
Adjusted to Year end 2018 $	$10.3 million	$13.6 million	$15.2 million
Income Elasticity[26].	0.775	1.00	1.44
Annual Real Income Growth	1.93%	1.93%	1.93%
NFDL Percent VSL	0.39% VSL	0.75% VSL	0.75% VSL
NFDL 2018 Value	$0.04 million	$0.10 million	$0.11 million
NDL Percent VSL	0.16% VSL	0.27% VSL	0.66% VSL
NDL 2018 Value	$0.02 million	$0.04 million	$0.10 million

*Note: Calculations in the monetization tables use additional decimal places not shown here.

Selection of Values for NFDL and NDL Incidents

For past regulations, MSHA has assigned a value of $50,000 or 0.7 percent of VSL for non-disabling lost workday injuries. For this analysis, MSHA applied the 0.7 percent to the VSL for

[24] DOT (2014).

[25] Kniesner, T.J., W.K. Viscusi and J.P. Ziliak (2010). "Policy Relevant Heterogeneity in the Value of Statistical Life: New Evidence from Panel Data Quantile Regressions." *Journal of Risk and Uncertainty.* 40(1): 15-31.

[26] In 2012 DOT updated its guidance to use an elasticity of 1.0. Most of the articles in note 11 above also include an income elasticity of 1.0 or higher.

the NFDL value. MSHA examined two other sources of cost estimates for NFDL and NDL incidents. The National Safety Council (NSC) provides a value of $39,000 (2016 dollars) inclusive of medical expenses treatment, administrative expenses, employer expenses, and loss of workplace productivity, for incidents that include NDL[27]. Adjusting this value to 2018 dollars using the Medical CPI, the NFDL value is $40,000.[28] For the NFDL benefit estimate, MSHA used the 0.7 percent value used in past regulations. The NIOSH also has published estimates. The NIOSH estimate includes values that can be used for NDL incidents. Based on past practice, MSHA assumed a value of 0.3 percent of VSL.

Table 4-5 shows the values used by year for VSL, NFDL, and NDL. These values represent the base VSL value for 2018 as adjusted each additional year based on the real income growth and elasticity as presented in 4-5 and the step 2-4 of the VSL Estimate section above. MSHA rounded values for display purposes. The additional analysis and tables in Chapter 5 Net Benefits use the additional decimal places and include calculations at 3 percent and 7 percent discount rates in all calculations.

Table 4-5: Annual Values for VSL and Non-fatal Injuries

Year	VSL ($ millions)	NFDL ($ millions)	NDL ($ millions)
1	$13.90	$0.10	$0.04
2	$14.16	$0.11	$0.04
3	$14.44	$0.11	$0.04
4	$14.71	$0.11	$0.04
5	$15.00	$0.11	$0.04
6	$15.28	$0.11	$0.04
7	$15.58	$0.12	$0.04
8	$15.88	$0.12	$0.04
9	$16.18	$0.12	$0.04
10	$16.50	$0.12	$0.04

Table 4-6 presents the estimates of the benefit dollars by multiplying the corresponding incident-prevented numbers of Table 4-2 and the Table 4-5 dollar values for VSL, NFDL, and NDL incidents. MSHA assumes the first year will have 10 percent of the full year impact. Years two through ten assume elimination of the baseline trend incidents. The calculations use additional decimals than shown in the display, which may affect totals and independent rounding.

Table 4-6: Monetized Benefit Estimates - Undiscounted:
(Table 4-2 incident numbers times Table 4-5 dollar values)

[27] National Safety Council, "National Safety Council, Injury Facts 2015 Edition".

[28] National Safety Council listed the 2016 cost at $39,000. Adjusting this 2016 value to 2018 using the medical CPI, (CUSR0000SAM2 Consumer Price Index for All Urban Consumers: Medical Care Services in U.S. City Average, Index 1982-1984=100, Annual, Seasonally Adjusted) the resulting value is $40,000.

Year	Prevented Fatalities ($ millions)	Prevented NFDL ($ millions)	Prevented NDL ($ millions)	Annual Total* ($ millions)
1	6.7	0.4	0.1	7.1
2	68.2	3.5	0.6	72.3
3	69.1	3.3	0.6	73.0
4	70.6	3.0	0.6	74.1
5	72.0	2.8	0.5	75.4
6	73.4	2.6	0.5	76.6
7	74.9	2.7	0.5	78.1
8	76.3	2.4	0.5	79.2
9	77.8	2.2	0.5	80.5
10	79.2	2.0	0.6	81.9
Total*	668.2	24.9	5.0	698.2
*Totals are based on the detailed data without rounding of the individual table cells.				

5. NET BENEFITS

Introduction

This chapter presents a summary of MSHA's estimates of the net benefits of the proposed rule. Under the Mine Act, MSHA is not required to use the estimated net benefits as the basis for its regulatory decisions.

MSHA's 10-year cost and benefit estimates are shown in Table 5-1. Under MSHA's proposed rule, mine operators would be required to develop and implement a written safety program 6 months after the final rule takes effect. MSHA believes that this twelve-month period would provide mine operators time to develop and communicate the safety program to employees, evaluate mine operations for hazards, and eliminate and control identified hazards (e.g., engineering controls, work practices, and equipment maintenance). MSHA assumes that full annual benefits of the proposed rule (80 percent reduction in projected fatalities and non-fatal injuries) would be achieved starting from the second year, with benefits equal to 10 percent of that amount in the first year. MSHA requests public comment on its assumptions and methodology in this net benefits analysis.

Table 5-1: Summary of Benefits, Costs, and Net Benefits ($ millions)*

Year	Undiscounted			3 Percent Discount Rate				7 Percent Discount Rate			
	Benefits	Costs	Net Benefits	Discount Factor	Discounted Benefits	Discounted Costs	Discounted Net Benefits	Discount Factor	Discounted Benefits	Discounted Costs	Discounted Net Benefits
1	$7.1	$56.7	-$49.6	0.970874	$6.9	$55.0	-$48.2	0.934579	$6.6	$53.0	-$46.4
2	$72.3	$12.3	$60.0	0.942596	$68.1	$11.6	$56.6	0.873439	$63.1	$10.7	$52.4
3	$73.0	$12.3	$60.7	0.915142	$66.8	$11.3	$55.5	0.816298	$59.6	$10.0	$49.5
4	$74.1	$12.3	$61.8	0.888487	$65.8	$10.9	$54.9	0.762895	$56.5	$9.4	$47.1
5	$75.4	$12.3	$63.1	0.862609	$65.0	$10.6	$54.4	0.712986	$53.8	$8.8	$45.0
6	$76.6	$12.3	$64.3	0.837484	$64.2	$10.3	$53.9	0.666342	$51.0	$8.2	$42.8
7	$78.1	$12.3	$65.8	0.813092	$63.5	$10.0	$53.5	0.622750	$48.6	$7.7	$41.0
8	$79.2	$12.3	$66.9	0.789409	$62.5	$9.7	$52.8	0.582009	$46.1	$7.2	$38.9
9	$80.5	$12.3	$68.2	0.766417	$61.7	$9.4	$52.3	0.543934	$43.8	$6.7	$37.1
10	$81.9	$12.3	$69.6	0.744094	$60.9	$9.2	$51.8	0.508349	$41.6	$6.3	$35.4
Total	$698.2	$167.4	$530.8		$585.5	$148.0	$437.5		$470.9	$127.9	$343.0
Annualized	$69.8	$16.7	$53.1		$66.6	$16.8	$49.8		$62.7	$17.0	$45.6

* Values in millions. Full precision of numbers calculated and summed, but independent rounding for display purposes affects subtotals but not the underlying calculations.

Sensitivity Analysis

Table 5-2 summarizes the estimates of monetized incremental benefits and costs developed for the proposed rule. All benefits and costs are estimated for a 10-year time horizon since the final rule takes into effect and converted to annualized net benefits at two values using discount rates of 7 and 3 percent. Three scenarios are presented illustrating annualized benefits and costs of the proposed rule using alternative scenarios described earlier. Scenario 1 assumes the proposed parameters that are not based on published estimates (i.e., are assumptions made). These three scenarios include: two scenarios of lower net benefit (using safety program effectiveness rates which result in reducing the projected lower benefits) and an expected scenario (consisting of expected values for assumed parameters). Under low net benefit Scenario 1, fatalities and non-fatal injuries are assumed to be reduced by 20 percent, whereas Scenario 2 assumes the program would reduce the projected, fatalities and non-fatal injuries are by 50 percent.

Table 5-2: Monetized Cost and Benefits Based Upon Level of Safety Effectiveness

	Low Net Benefit Scenario 1 (20% reduction)		**Low Net Benefit Scenario 2 (50% reduction)**		**Expected Scenario (80% reduction)**	
Monetized Costs and Benefits	7-Percent Discount Rate	3-Percent Discount Rate	7-Percent Discount Rate	3-Percent Discount Rate	7-Percent Discount Rate	3-Percent Discount Rate
Annualized Value of Monetized Benefits	$15.7	$16.7	$39.2	$41.6	$62.7	$66.6
Annualized Value of Monetized Costs	$17.0	$16.8	$17.0	$16.8	$17.00	$16.8
Annualized Value of Net Benefits	-$1.4	-$0.2	$22.2	$24.8	$45.6	$49.8

Break-Even Point Analysis

OMB Circular A-4 permits use of a break-even or threshold analysis when there are non-quantified benefits or issues of uncertainty related to the cost and benefit estimates. As discussed above, MSHA's estimates of the benefits of the rule are based on the projected reduction in the number of fatalities and injuries. (MSHA believes it is likely that the severity of injuries would also be reduced, creating an additional benefit, but this benefit is not quantified.) The success of the proposed rule in reducing the number of fatal and nonfatal injuries can be considered in terms of the resulting monetized benefit. A break-even point is when net benefits (monetized benefits minus costs) equal zero. According to the break-even calculations for this proposal, even if the fatalities and injuries are not reduced as forecasted, the reduction of fatal and nonfatal injuries would have a positive net benefit as long as those injuries are reduced by more than 27.1 percent; at 27.1 percent, the net benefits at a 7 percent discount rate would equal zero.

Regulatory Alternative

As discussed earlier, MSHA considered various approaches to hazards associated with surface mobile equipment. The RFI (83 FR 29716) and stakeholder meetings (83 FR 35157) held throughout the country yielded a great deal of information about available and emerging technologies, include the pace at which technological developments were occurring. Through the stakeholder meetings, MSHA came to a conclusion that prescribing a particular set of technology would not be optimal given the pace of emergence of new technology. The comparatively rapid development and distribution of such technology made a prescriptive approach less than optimal – were MSHA to require specific mechanisms or specify a one-size-fits-all program, new developments and unique characteristics of particular mines and localities could quickly render such a standard obsolete.

Thus, MSHA turned to a performance-based program approach. Within that approach there were two options – one, to require mines of any size to develop and implement a written safety program for surface mobile equipment; the; the other, to omit some mines from the scope of a proposed rule. After careful consideration and analysis of available accident data, MSHA determined that the smallest mines, those with five or fewer miners working on the surface, tend to have fewer pieces of equipment and less complex surface operations than larger mines. These smaller mines would incur significant costs to develop and implement such a written safety program. MSHA determined to omit mines with five or fewer miners from the scope of the rule.

MSHA estimates that there are 7,254 mines with five or fewer miners. The preliminary projected costs for this group of mines would add up to approximately undiscounted cost of $170 million over a ten-year period. These mines would incur a start of cost of $51.66 million in the first year and an annual cost of $5.6 for a total cost of $50.4 over the following 9 years after the first year in Safety Program Development Costs. Table 5-3 below shows the estimated cost components of the Safety Program for the 7,254 mines.

Table 5-3: Safety Program Development Costs for Mines with 5 or Fewer Miners

Major Safety Program Elements*	Mine Task Hours (Annual)	Total Hours (task hours x 7,254 mines)	Startup ($ millions)	Out-year Annual ($ millions)
Identifying hazards and manage risks	15	108,810	$7.0	$0.0
Evaluating technologies that enhance safety	60	435,240	$28.1	$0.0
Summarizing findings and developing written program	20	145,080	$9.4	$0.0
Clerical assistance to finalize program (clerical rate $31.03)	30	217,620	$6.7	$0.0
Reevaluating workplace activities due to changes in technology, conditions, processes, materials, or equipment; conducting on-site examinations; identifying hazards, trends, root causes, and take corrective actions	10	72,540	$0.0	$4.7
Annual review and update of the safety program	2	14,508	$0.0	$0.9
Total using an overhead of 1%			$51.6	$5.6

In addition to the safety program development costs shown in the above table, there are approximately 18,006 pieces of equipment situated at these mines that could need equipment safety enhancement, including maintenance, and seatbelt interlocking devices for a total cost of $68.3 million over a ten-year period.

Mines with five or fewer miners experienced 10 fatalities related to surface mobile equipment between 2013 and 2018. Mines with 6 or more miners experienced 109 related fatalities in that same time period. MSHA requests comment on this alternative and on the estimated regulatory impacts stated above.

6. REGULATORY FLEXIBILITY ANALYSIS AND SMALL BUSINESS REGULATORY ENFORCEMENT FAIRNESS ACT AND EXECUTIVE ORDER 13272: PROPER CONSIDERATION OF SMALL ENTITIES IN AGENCY RULEMAKING

Introduction

MSHA has reviewed the proposed rule to assess and take appropriate account of its potential impact on small businesses, small governmental jurisdictions, and small organizations. Pursuant to the Regulatory Flexibility Act (RFA) of 1980, as amended by the Small Business Regulatory Enforcement Fairness Act (SBREFA), MSHA analyzed the impact of the proposed rule on small entities. Based on that analysis, MSHA believes that this proposed rule would not have a significant economic impact on a substantial number of small entities. The Agency, therefore, is not required to develop an initial regulatory flexibility analysis. The factual basis for this proposed certification is presented below.

Definition of Small

Under the RFA, in analyzing the impact of a rule on small entities, MSHA must use the Small Business Administration's (SBA's) definition for a small entity, or after consultation with the SBA Office of Advocacy, establish an alternative definition for the mining industry by publishing that definition in the Federal Register for notice and comment.

The SBA uses North American Industry Classification System (NAICS) codes, generally at the 6-digit NAICS level, to set thresholds for small business sizes for each industry. See Table 6-1 for SBA thresholds for each relevant NAICS code. The SBA size standard tables and methodology are available at https://www.sba.gov/contracting/getting-started-contractor/make-sure-you-meet-sba-size-standards/summary-size-standards-industry-sector.

Factual Basis for Certification

The SBA guidance recommends, as a first step, a threshold analysis. MSHA evaluates the impacts on small entities by comparing the estimated compliance costs of a rule for small entities in the sector affected by the rule to the estimated revenues for the affected sector. As the threshold analysis is developed, MSHA considers the data availability as well as the degree of representativeness if the data is disaggregated. When estimated compliance costs are less than 1 percent of the estimated industry revenues, it is generally appropriate to conclude that there is no significant economic impact on a substantial number of small entities. MSHA examines data for the NAICS codes that have much higher impact ratios (cost/revenue) than others to ensure that the first level screening is representative. When estimated ratios may not be representative or when compliance costs exceed 1 percent of revenues, MSHA investigates whether further analysis is required.

For this analysis, MSHA evaluated a number of data sources related to the number of firms, employment, and revenue. MSHA concluded that the most useful data for firms and employment was the MNM mine data from MSIS, which is publicly available at https://www.msha.gov/data-reports/data-sources-calculators. Using the SBA criteria (see Table 6-1) and MSIS total average annual mine employment data as provided by mine operators, MSHA identified that 10,278 out of 12,281 mines and facilities are considered to be "small." Of those small mines and facilities, slightly more than one-third, 35 percent (3,557/10,278 small), would be required to comply with the provisions of the proposal, because they employ six or more miners. Costs from the Compliance Costs outlined in chapter 3 above, were distributed using the SBA small and large sizes using the same methodology discussed in that section. The 65 percent of small mine operators that do not have to comply will have no cost.

MSHA estimates mine revenue as it did in the past. Since MNM mines do not report production, MSHA used USGS Commodity reports (USGS, 2019) to obtain national MNM revenue numbers for 2018. MSHA allocated the NAICS code revenue for MNM mines on a dollar per hour basis. MSHA used the mine operator-reported coal production and Energy Information Administration price per ton for anthracite, lignite, and bituminous coal[29] for small mines.

MSHA considered the issue of disaggregation of summary data and displaying representative data for mines with five or fewer miners. The revenue per hour for MNM mines and per ton for coal is representative for the total as most mines meet the SBA's small criteria. However, MSHA believes it is unlikely to be representative for the smallest mines. MSHA requests comments and data that would assist MSHA in estimating representative revenues for the categories of six or more and five or fewer miners.

Table 6-1 shows the estimated revenues as described above, costs, SBA size standards (Feb. 2019), and the summary level screening test results for the total small mine revenue for each 6-digit NAICS code. The summary level data is consistent with evaluating the impact on a mine-by-mine basis without providing detail on all mines. The data allows each operator to use the Table 6-1 data to compare the revenue per mine and cost per mine to their operating data. Additionally, MSHA identified numerous data records that were incomplete, such as for new mines, mines that are intermittent with very few producing hours during the year, and mines that stopped producing in 2018. However, the revenue for incomplete data was less than 1 percent of total revenues and therefore small enough to not affect MSHA's decision to propose to certify that there would be no significant economic impact on a substantial number of small entities.

[29] https://www.eia.gov/coal/annual/archive/0584_2018.pdf, p. XVII

Table 6-1: Summary of Small Business Screening Data
(Revenues and Cost in $ millions)

NAICS Code	NAICS Description	Small Standard (max no. of employees)	No. Small Mines	Estimated Revenue All Small Mines	One Percent of Revenues	Cost to All Small Mines	Cost Exceeds One Percent
212111	Bituminous Coal and Lignite Surface Mining	1,250	611	$9,325	$93.25	$4.48	No
212112	Bituminous Coal Underground Mining	1,500	148	$4,386	$43.86	$0.33	No
212113	Anthracite Mining	250	117	$189	$1.89	$0.38	No
212210	Iron Ore Mining	750	21	$999	$9.99	$0.16	No
212221	Gold Ore Mining	1,500	122	$2,332	$23.32	$0.63	No
212222	Silver Ore Mining	250	5	$99	$0.99	$0.01	No
212230	Copper, Nickel, Lead, and Zinc Mining	750	27	$2,780	$27.80	$0.31	No
212291	Uranium-Radium-Vanadium Ore Mining	250	4	$0	$0.00	$0.01	Yes
212299	All Other Metal Ore Mining	750	17	$419	$4.19	$0.13	No
212311	Dimension Stone Mining and Quarrying	500	772	$438	$4.38	$3.15	No
212312	Crushed and Broken Limestone Mining and Quarrying	750	1,318	$6,459	$64.59	$7.64	No
212313	Crushed and Broken Granite Mining and Quarrying	750	138	$1,135	$11.35	$0.97	No
212319	Other Crushed and Broken Stone Mining and Quarrying	500	874	$1,732	$17.32	$3.52	No
212321	Construction Sand and Gravel Mining	500	5,326	$6,796	$67.96	$12.77	No
212322	Industrial Sand Mining	500	249	$4,231	$42.31	$1.34	No
212324	Kaolin and Ball Clay Mining	750	7	$620	$6.20	$0.05	No
212325	Clay and Ceramic and Refractory Minerals Mining	500	198	$766	$7.66	$0.78	No

NAICS Code	NAICS Description	Small Standard (max no. of employees)	No. Small Mines	Estimated Revenue All Small Mines	One Percent of Revenues	Cost to All Small Mines	Cost Exceeds One Percent
212391	Potash, Soda, and Borate Mineral Mining	750	9	$909	$9.09	$0.05	No
212392	Phosphate Rock Mining	1,000	8	$969	$9.69	$0.16	No
212393	Other Chemical and Fertilizer Mineral Mining	500	44	$1,541	$15.41	$0.28	No
212399	All Other Nonmetallic Mineral Mining	500	181	$957	$9.57	$0.89	No
311942	Spice and Extract Manufacturing	500	3	$920	$9.20	$0.02	No
327310	Cement Manufacturing	1,000	40	$4,501	$45.01	$0.43	No
327410	Lime Manufacturing	750	31	$1,350	$13.50	$0.24	No
331313	Alumina Refining and Primary Aluminum Production	1,000	6	$3	$0.03	$0.04	Yes
Grand Total			10,278	$53,856	$538.56	$38.77	No

Note: Total number of small mines includes 2 mines that were not reported as abandoned but lacked hours and sufficient information to assign revenues. Without miner hours, costs and revenues related to the NAICS codes above are most likely zero.

As Table 6-1 shows, the total estimated cost to small mines, $38.77 million, is far less than 1 percent of the total revenues of those mines, which comes to $538.56 million. Two NAICS codes, 331313 Alumina Refining and Primary Aluminum Production and 212291 Uranium Radium-Vanadium Ore Mining, require further analysis, because estimated costs for those codes exceed MSHA's 1-percent threshold for additional analysis. The Census Bureau's Statistics of U.S. Businesses and 2017 Economic Census data provides helpful information for additional analysis of NAICS code 331313. The Census Bureau reports that all data for NAICS code 212291 has been withheld due to the very limited number of mines. The six mines and plants regulated by MSHA with NAICS code 331313 are only a portion of the larger group of all firms with NAICS code 331313. The preliminary data from the Economic Census as shown in the Bureau's data does not provide enough detail to separate small firms between 500 and 1,000 employees from their total for 500 and more employees or to isolate mines from all firms with NAICS code 331313. [30]

[30] See https://www2.census.gov/programs-surveys/susb/tables/2017/us_6digitnaics_2017.xlsx for the available data.

For NAICS code 331313, MSHA's estimate for the total costs for the small firms that it regulates within this NAICS code is $38,500. The Economic Census reports the smallest firms (fewer than 20 employees) for this NAICS code have preliminary receipts of $9.3 million. Thus, the impact for the smallest firms in NAICS code 331313 would only be 0.4 percent ($38,500/$9,300,000). The overall percentage impact to small firms goes down as the revenues increase for the rest of the firms up to the SBA threshold of 1,000 employees. Although the Economic Census numbers are for 2017, information available online provided by a private firm SICCODE.com (https://siccode.com/naics-code/331313/alumina-refining-primary-aluminum-production) suggests that the number of firms (26) and total revenues ($3 billion) for all firms in this NAICS code are down slightly for 2018 but not enough to alter MSHA's conclusion that there is no significant impact for small firms with this NAICS code.

For Uranium and Vanadium, the mines were rarely in production in 2018. Reviewing several web sources suggests that as uranium approaches or maintains zero production, the Vanadium mines have the potential for growth in the future for use in steel and battery production. Even though the mines are essentially non-producing, mines are maintained for the future potential. Because no recent data is available regarding the remaining establishments and their total employment, revenues, or costs, it is not possible to compute the impact beyond the total cost for NAICS code 212291 which is slightly over $14,000. Considering that the firms owning the limited number of mines are maintaining the mines for future possibilities, it is unlikely that $14,000 would change their choices whether to close and would not consider the total low cost as a significant impact. MSHA invites comments and data that might improve this conclusion and analysis.

7. PAPERWORK REDUCTION ACT OF 1995

Introduction

This section shows the estimated paperwork burden hours and related burden costs for the mine operators affected by the proposed rule. The burden hour and cost estimates presented in this chapter use the detailed analysis of all costs over ten years presented in Chapter 3. This chapter provides only information collection costs for 3 years presented as average annual values. The cost items in this chapter are a subset of the total costs in Chapter 3, and only relate to information collection requirements.

Summary of Paperwork Burden Hours and Related Costs

This proposed rule would create new information collection burdens for the mining community. The new burden applies only to mine operators with six or more miners. As stated in the proposal, mine operators would have wide latitude to develop and implement a written safety program. Mine operators could also consult or use examples of model written safety programs available at MSHA's website. MSHA recognizes that this proposed rule could transfer burden from (or add burden to) existing information collections such as those related to training or equipment maintenance. However, MSHA is requesting a new OMB Control Number until the Agency determines how the burden under this proposal would affect MSHA's existing information collections. Using the data from the E.O. 12866 analysis, MSHA estimates that, for the first 3 years of the proposal implementation, 5,027 respondents (mine operators employing six or more miners) would incur, on average, an annual collection burden of 100,540 hours, with an annual burden cost estimate of $4.8 million. (See Table 7-1.) The MSHA enforcement staff would not review all written programs, but any program review would be part of routine mine inspections and therefore there is no new federal cost.

Table 7-1: Recordkeeping Burden of Proposed Rule

Year	Item Description	Hours per Task	Respondents (Mines)	Burden Hours	Hourly Rate (with Benefits)	Hour Burden Cost ($ Millions)
1	Development of a written safety program	20	5,027	100,540	$65.10	$ 6.5
1	Clerical assistance to finalize written program	30	5,027	150,810	$ 31.46	$ 4.7
2	Annual review, plan revision, and update due to changes in workplace activities	5	5,027	25,135	$ 65.10	$ 1.6

Year	Item Description	Hours per Task	Respondents (Mines)	Burden Hours	Hourly Rate (with Benefits)	Hour Burden Cost ($ Millions)
3	Annual review, plan revision, and update due to changes in workplace activities	5	5,027	25,135	$ 65.10	$ 1.6
3-Year Total		60	5,027	301,620	NA	$ 14.4
Annual Average		20	5,027	100,540	NA	$ 4.8

8. OTHER REGULATORY CONSIDERATIONS

The Unfunded Mandates Reform Act of 1995

The Unfunded Mandates Reform Act of 1995 (Act) (2 U.S.C. 1501 *et seq.*) requires Federal agencies to assess the effects of their discretionary regulatory actions. In particular, the Act addresses actions that may result in the expenditure by state, local, or tribal governments, in the aggregate, or by the private sector, of $100 million (adjusted annually for inflation) or more in any one year. This proposed rule would not result in such an expenditure. Accordingly, the Unfunded Mandates Reform Act requires no further Agency action or analysis.

The Treasury and General Government Appropriations Act of 1999: Assessment of Federal Regulations and Policies on Families

Section 654 of the Treasury and General Government Appropriations Act of 1999 (5 U.S.C. 601 note) requires agencies to assess the impact of Agency action on family well-being. MSHA has determined that the proposal would not have an effect on family stability or safety, marital commitment, parental rights and authority, or income or poverty of families and children. Accordingly, MSHA certifies that this proposed rule would not impact family well-being.

Executive Order 12630: Government Actions and Interference with Constitutionally Protected Property Rights

Section 5 of E.O. 12630 requires federal agencies to "identify the takings implications of final regulatory actions …." MSHA has determined that the proposal would not include a regulatory or policy action with takings implications. Accordingly, E.O. 12630 requires no further Agency action or analysis.

Executive Order 12988: Civil Justice Reform

Section 3 of E.O. 12988 contains requirements for Federal agencies promulgating new regulations or reviewing existing regulations to minimize litigation by eliminating drafting errors and ambiguity, providing a clear legal standard for affected conduct rather than a general standard, promoting simplification, and reducing burden. MSHA has reviewed the proposal and has determined that it would meet the applicable standards provided in E.O. 12988 to minimize litigation and undue burden on the Federal court system.

Executive Order 13045: Protection of Children from Environmental Health Risks and Safety Risks

MSHA has determined that the proposal would not have an adverse impact on children. Accordingly, E.O. 13045 requires no further Agency action or analysis.

Executive Order 13132: Federalism

MSHA has determined that the proposal would not have federalism implications because it would not have substantial direct effects on the States, on the relationship between the national government and the States, or on the distribution of power and responsibilities among the various levels of government. Accordingly, E.O. 13132 requires no further Agency action or analysis.

Executive Order 13175: Consultation and Coordination with Indian Tribal Governments

MSHA has determined that the proposal would not have tribal implications because it would not have substantial direct effects on one or more Indian tribes, on the relationship between the Federal Government and Indian tribes, or on the distribution of power and responsibilities between the Federal Government and Indian tribes. Accordingly, E.O. 13175 requires no further Agency action or analysis.

Executive Order 13211: Actions Concerning Regulations That Significantly Affect Energy Supply, Distribution, or Use

E.O. 13211 requires agencies to publish a statement of energy effects when a rule has a significant energy action that adversely affects energy supply, distribution, or use. MSHA reviewed the proposal for its energy effects on the production of coal and uranium mining. The proposal would result in annualized costs of approximately $16.7 million (undiscounted) to covered surface mines and surface areas of underground mines. The Energy Information Administration's annual uranium report for 2018 (p. 1) shows, "Owners and operators of U.S. civilian nuclear power reactors (civilian owner/operators, or COOs) purchased a total of 43 million pounds U3O8e (equivalent) of deliveries from U.S. suppliers and foreign suppliers during 2017, at a weighted-average price of $38.80 per pound," which is approximately $1.7 billion (43 million pounds x $38.80 per pound). Given that domestic nuclear plants represent only 19.3 percent of the U.S. electrical production and using average annual costs of the entire proposal, the impact to the domestic energy production could not reach 1 percent. The coal mining industry has an annual revenue of $27.2 billion (See Table 2-2). Under this proposal, annual costs impacting the total coal production of 756 million tons in 2018 would not affect national energy production costs by more than 1 percent or reduce annual coal production by 5 million tons. MSHA has concluded that it is not a significant energy action because it is not likely to have a significant adverse effect on the supply, distribution, or use of energy. Accordingly, under this analysis, no further Agency action or analysis is required.

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APPENDIX A: TECHNICAL APPENDICES INTRODUCTION

Overview

The technical appendices provides basic statistics, data, and charts showing the history of injuries and fatalities used for the Benefits chapter as well as the future basic projection documentation. The history reflects incident reports from 2003-2018 that this proposed rule could have prevented as discussed in the Benefits chapter of the evaluation. Once MSHA developed the baseline data set, the following process was used:

1. Refine the raw data set of reported fatalities and injuries to reflect the covered equipment and incidents that the proposal could prevent.
2. Convert the refined data set reported number of fatalities and injuries for the equipment covered by the proposed rule to incident rates. These rates reflect the incident rates specific to either coal or metal nonmetal (MNM) and limited to the refined dataset. These calculated rates may or may not track with the overall mining incident rates, as the included data is a subset of the total (See Appendix B). For the appendices, MSHA has minimized the shortening of metal nonmetal to MNM as those same letters refer to model selection options in EViews that was used for modeling. The variable names needed a shortened name so that model and estimation descriptors could be added to outputs automatically. MSHA believes the context where the terms appear are sufficient to avoid confusion.
3. Develop a forecast of the baseline trend (See Appendices C and D).
4. Develop an hours forecast separately for coal and metal nonmetal (See Appendices E and F).
5. Final; Convert the baseline forecast incident rate back to the number of fatalities and injuries. Both the main body of the evaluation and following appendices detail each step of the process and models used (See Appendix G).

Definitions and Notes

(From the 2018 Mine Injury and Worktime, Quarterly, January–December 2018, Final https://arlweb.msha.gov/Stats/Part50/WQ/2018/MIWQ Report CY 2018.pdf).

The term “injury,” as used in this publication, includes all reportable occupational injuries and those illnesses, which result from a work accident or from exposure involving a single incident in the work environment. A reportable “injury” is an injury to an individual, occurring at a mining operation that requires medical treatment or results in death or loss of consciousness or inability to perform all job duties on any workday after the injury or temporary assignment to other duties or transfer to another job. The injury occurrences are classified according to severity as follows:

1. FATAL: Occurrences resulting in death.
2. NFDL: Nonfatal occurrences with Days Lost (lost workdays). That is, nonfatal injury occurrences than result in days away from work or days of restricted work activity.
3. NDL: Occurrences with No Days Lost. That is, nonfatal injury occurrences resulting only in loss of consciousness or medical treatment other than first aid.

Incidence rates represent the number of injuries that occurred for each 200,000 employee hours worked, computed as follows:

IR = (Number of Injury Occurrences ÷ Number of Employee Hours) × 200,000

Historical Data Set Variable Description

Table A-1: Historical Hours, Injuries, Fatalities, and Computed Incident Rate Variables

Variables	Variable Definition
Coal_EH	Coal Employee Hours (Total Industry)
MNM_EH	Metal Nonmetal Employee Hours (Total Industry)
Coal_F	Coal Fatalities Incidents (Only Incidents the Rule Could Reduce)
Coal_NFDL	Coal Nonfatal Days Lost Incidents (Only Incidents the Rule Could Reduce)
Coal_NDL	Coal Nonfatal No Days Lost Incidents (Only Incidents the Rule Could Reduce)
M_F	Metal Nonmetal Fatalities Incidents (Only Incidents the Rule Could Reduce)
M_NFDL	Metal Nonmetal Nonfatal Days Lost Incidents (Only Incidents the Rule Could Reduce)
M_NDL	Metal Nonmetal Nonfatal No Days Lost Incidents (Only Incidents the Rule Could Reduce)
CF_IR_2	Coal Fatalities Incident Rate (Only Incidents the Rule Could Reduce)
CNFDL_IR	Coal Nonfatal Days Lost Incident Rate (Only Incidents the Rule Could Reduce)
CNDL_IR	Coal Nonfatal No Days Lost Incident Rate (Only Incidents the Rule Could Reduce)
MF_IR	Metal Nonmetal Fatal Incident Rates (Only Incidents the Rule Could Reduce)
MNFDL_IR	Metal Nonmetal Nonfatal Days Lost Incident Rate (Only Incidents the Rule Could Reduce)
MNDL_IR	Metal Nonmetal Nonfatal No Days Lost Incident Rate (Only Incidents the Rule Could Reduce)

Incident Rate Forecast Methodology

For the incident rate trends, MSHA created a forecast using the econometric software package EViews using a method known as Error-Trend-Seasonal Exponential Smoothing (ETS) [31]. The EViews help system defines ETS as follows (definition edited for brevity):

EViews 8 uses the dynamic nonlinear model framework of Hyndman, Koehler, et al. (2002). The ETS (Error-Trend-Seasonal or Exponential Smoothing) framework defines an extended class of exponential smoothing methods that encompasses standard ES models (e.g., Holt and Holt–Winters additive and multiplicative methods), but offer a variety of new methods.

The ETS methodology compares up to thirty different combinations of smoothing specifications. Some combinations of the estimated parameters may not result in an automatic full set of model solution such as no trend, no seasonality, or models that do not converge on a solution. When division by zero occurs or when the historical series is too short, a modified model selection is necessary. Additionally the automated method of selecting some of the combinations requires a longer data series history than the data series MSHA reviewed. The parameters relate to the presence or absence of trend and seasonality. The additive and multiplicative models are considered for both damped and non-damped trend methodologies. The error term accounts for the irregular or unpredictable component of the series being analyzed. This results in the following matrix of possibilities that are represented by the first letter of the component, except for damped models where damped methods are added to the additive or multiplicative method. The letters in the table below are shown for each selected forecast model of incident rates. For any of the models estimated with ETS, the resulting number of possibilities for each term and the total number of possible combinations is shown in Table A-2.

Table A-2: ETS Terms, Methods, and Possibilities

Term	**Method**	**Number of Possibilities**
E: Error term	A: Additive; M: Multiplicative	2
T: Trend	N: None; A: Additive; M: Multiplicative; AD: Additive Damped; MD: Multiplicative Damped	5
S: Seasonality	A: Additive; M: Multiplicative; N:None	3
Number of possibilities = 2 x 5 x 3		30

MSHA used the default settings for traditional smoothing. ETS uses an iterative process to optimize an estimate when possible. The EViews ETS smoothing settings were set to automatic except for the estimates that could not be solved with the auto settings. For these few instances, solutions were estimated with the trend set to additive and the error set to auto. For final model

[31] See http://www.EViews.com/general/about_us.html

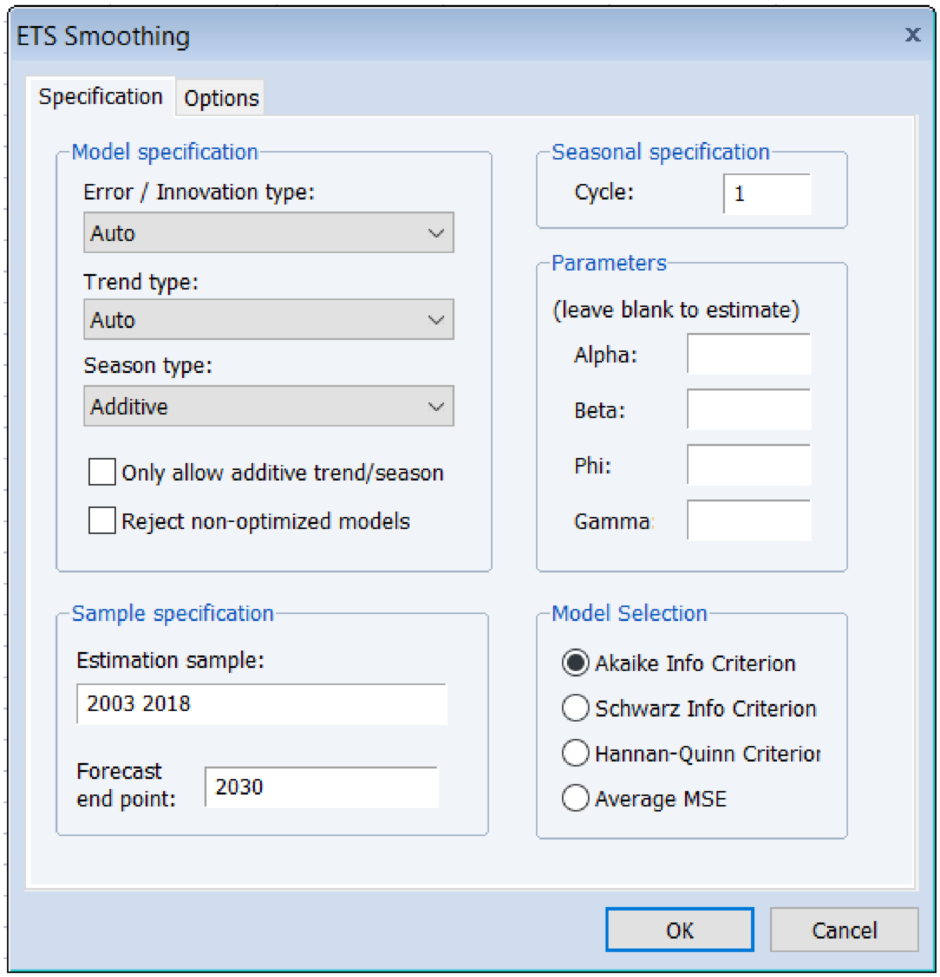
selection, MSHA considered two model selection criteria: the Akaike Information Criterion (AIC) and the Average Mean Squared Error statistic. The AIC is one of a number of criteria used to evaluate models and evaluate both model fit and complexity. The AIC represents a quality statistic that is used to compare model selections within the same class of modeling. The AIC cannot be used to compare models with different methodologies such as comparisons among smoothing, regressions, or Box-Cox estimations. Holding everything else constant, the AIC provides a better score (lower value) to models that minimize differences from actual data values while at the same time utilizing the least number of variables necessary to explain differences in the models. For exponential smoothing of single variables, the AIC value computes a better score for fewer parameters when the same model forecast is produced.

MSHA also considered model selection criteria based on the average mean squared error (MSE) and root mean squared error (RMSE), particularly when the AIC values differed only slightly due to the number of smoothing parameters. Both forms of the error selection criteria are based on the difference between the actual and fitted values for the historical period. The smaller the minimized average MSE, the better within sample one-step predictive forecast. As in all modeling, there is no perfect or single solution. MSHA compared the AIC values selection criterion reported by the automatic model selection and used the lowest AIC for models with the same number of parameters. When the no seasonality model results show the same average MSE terms and a slightly smaller AIC, MSHA selected the no seasonality model. For two forecasts, MSHA used a forecast override described within the related forecast appendix sections. The documentation in the following appendices display the model selected as well as the basic model information for each set of forecasts. Since the historical data was too short for fully automated estimation, the seasonal parameter could not be automatically selected. MSHA executed the ETS procedure three times for each ETS specification. The error and trend parameters were set at auto while the seasonal term was set to additive, then multiplicative, and then none for the third iteration. After completing the three forecasts, MSHA evaluated the AIC and Average MSE criterion for final model selection.

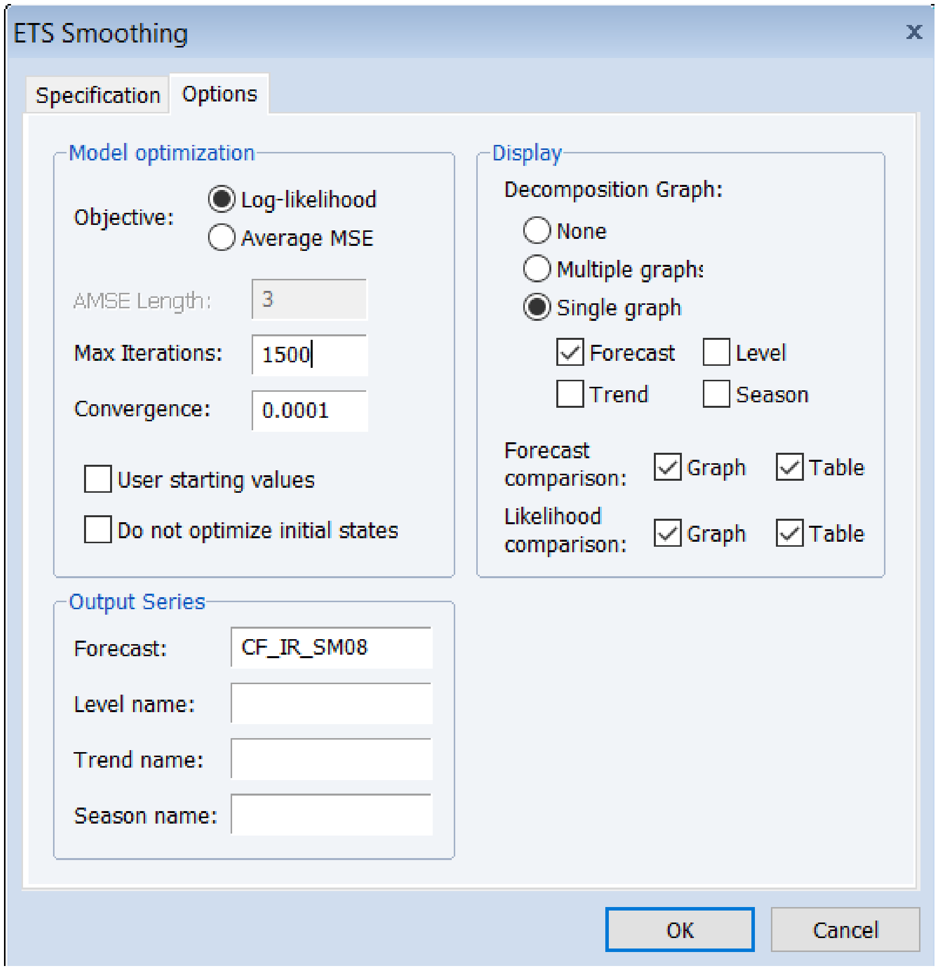
Sample EViews Procedure Menu

For modeling purposes, variables were assigned mnemonic names for forecasting variables. EViews then added sequential numerical values to identify the specific model forecast. The following figure shows the EViews ETS procedure for the auto specification of the Error and Trend terms along with manual selection of seasonality type[32]. While the second figure shows the optimization technique for estimating the parameters and the name of the output file for the estimated model.

[32] Used by permission, IHS Markit.


ETS Smoothing
Specification
Options
Model specification
Error / Innovation type:
Auto
Trend type:
Auto
Season type:
Additive
Only allow additive trend/season
Reject non-optimized models
Seasonal specification
Cycle:
1
Parameters
(leave blank to estimate)
Alpha:
Beta:
Phi:
Gamma
Sample specification
Estimation sample:
2003 2018
Forecast end point:
2030
Model Selection
Akaike Info Criterion
Schwarz Info Criterion
Hannan-Quinn Criterion
Average MSE
OK
Cancel

EViews ETS procedure options tab as shown in the previous figure:



APPENDIX B: HOURS, INCIDENTS, AND INCIDENT RATES

Incidence rates represent the number of injuries that occurred for each 200,000 employee hours worked, computed as follows:

IR = (Number of Injury Occurrences /Number of Employee Hours) × 200,000

Incidents used to calculate the incidence rates are those related to the equipment covered in the proposed rule and identified as having characteristics the proposal is designed to reduce or prevent. The Employee Hours are all non-administrative hours.

Coal

		Incidents			Incident Rates		
Year	Employee Hours	Fatal	NFDL	NFD	Fatal	NFDL	NFD
2003	150,818,604	6	24	7	0.007957	0.031826	0.009283
2004	159,921,424	4	35	15	0.005002	0.043771	0.018759
2005	174,362,615	5	33	25	0.005735	0.037852	0.028676
2006	181,859,979	2	42	13	0.002199	0.046189	0.014297
2007	179,120,116	4	32	12	0.004466	0.035730	0.013399
2008	192,697,482	4	30	17	0.004152	0.031137	0.017644
2009	187,653,879	5	36	15	0.005329	0.038369	0.015987
2010	191,627,899	3	30	10	0.003131	0.031311	0.010437
2011	208,029,731	2	36	10	0.001923	0.034610	0.009614
2012	193,063,045	2	19	7	0.002072	0.019683	0.007252
2013	175,828,115	1	16	5	0.001137	0.018200	0.005687
2014	166,106,385	3	15	15	0.003612	0.018061	0.018061
2015	141,054,637	2	16	5	0.002836	0.022686	0.007089
2016	108,629,068	0*	11	2	0.000000	0.020252	0.003682
2017	117,094,906	4	18	5	0.006832	0.030744	0.008540
2018	120,276,227	0*	20	6	0.000000	0.033257	0.009977

*Zero values require special handling when forecasting the incident rates. Although it is possible to have no fatalities or incidents in a year, such as no fatalities in 2016 and 2018, some estimation techniques failed to calculate or compute meaningful trends, particularly when the zero causes a division by zero error. One standard forecasting treatments of zeroes is to provide a minimum value that is very close to zero and small enough to avoid influencing the overall trend line. MSHA substituted 9×10^{-6} that eliminated division by zero and allowed successful model estimation without having a measurable impact on the forecasts that used this historical data.

Metal Nonmetal

Year	Employee Hours	Incidents			Incident Rates		
		Fatal	NFDL	NFD	Fatal	NFDL	NFD
2003	292,968,066	1	46	21	0.000683	0.031403	0.014336
2004	301,582,837	2	59	29	0.001326	0.039127	0.019232
2005	311,291,592	6	55	25	0.003855	0.035337	0.016062
2006	318,850,638	5	62	38	0.003136	0.038890	0.023836
2007	317,572,444	4	44	27	0.002519	0.027710	0.017004
2008	301,729,081	2	70	23	0.001326	0.046399	0.015245
2009	248,862,511	4	30	15	0.003215	0.024110	0.012055
2010	255,116,558	3	46	13	0.002352	0.036062	0.010191
2011	267,072,680	1	26	12	0.000749	0.019470	0.008986
2012	276,002,979	4	36	8	0.002899	0.026087	0.005797
2013	279,726,182	4	34	13	0.002860	0.024309	0.009295
2014	286,071,314	6	38	16	0.004195	0.026567	0.011186
2015	285,491,004	3	26	19	0.002102	0.018214	0.013310
2016	278,927,854	5	29	16	0.003585	0.020794	0.011473
2017	283,946,573	6	28	14	0.004226	0.019722	0.009861
2018	294,790,231	6	29	14	0.004071	0.019675	0.009498

Summary of Model Selection Outputs, Coal Fatality Incident Rate

The fully automatic method of ETS fails automatic selection of seasonality as the time series is too short. Manually executing the ETS procedure with the seasonality set to additive, multiplicative, and none results in the additive and multiplicative models using the same parameters and the same model diagnostics due to model convergence at the boundaries. All three seasonalities solve to the same model. For the coal fatality incident rate, the simplest model, A,M,N, was chosen as the forecast model. For each set of incident forecasting models, the models in Appendices C and D, the model specification and selection criteria are highlighted in blue. Non-selected models show the same items highlighted in yellow.

ETS Smoothing
Original series: CF_IR_2
Sample: 2003 2030
Included observations: 16
Model: A,M,A - Additive Error, Multiplicative Trend,
Additive Season (Auto E=*, T=*)
Model selection: Akaike Information Criterion
Convergence achieved on boundaries.

Parameters	
Alpha:	0.000000
Beta:	0.000000
Gamma:	0.000000

Initial Parameters	
Initial level:	0.006837
Initial trend:	0.915648
Initial state 1:	0.000000

Compact Log-likelihood	79.15721
Log-likelihood	78.63491

ETS Smoothing
Original series: CF_IR_2
Sample: 2003 2030
Included observations: 16
Model: A,M,M - Additive Error, Multiplicative Trend,
Multiplicative Season (Auto E=*, T=*)
Model selection: Akaike Information Criterion
Convergence achieved on boundaries.

Parameters	
Alpha:	0.000000
Beta:	0.000000
Gamma:	0.000000

Initial Parameters	
Initial level:	0.006837
Initial trend:	0.915648
Initial state 1:	1.000000

Compact Log-likelihood	79.15721

ETS Smoothing
Original series: CF_IR_2
Sample: 2003 2030
Included observations: 16
Model: A,M,N - Additive Error, Multiplicative Trend,
No Season (Auto E=*, T=*)
Model selection: Akaike Information Criterion
Convergence achieved on boundaries.

Parameters	
Alpha:	0.000000
Beta:	0.000000

Initial Parameters	
Initial level:	0.006837
Initial trend:	0.915648

Compact Log-likelihood	79.15721
Log-likelihood	78.63491
Akaike Information Criterion	-150.3144
Schwarz Criterion	-147.2241

Akaike Information Criterion	-148.3144	Log-likelihood	78.63491	Hannan-Quinn Criterion	-150.1562
Schwarz Criterion	-144.4515	Akaike Information Criterion	-148.3144	Sum of Squared Residuals	5.04E-05
Hannan-Quinn Criterion	-148.1166	Schwarz Criterion	-144.4515	Root Mean Squared Error	0.001776
Sum of Squared Residuals	5.04E-05	Hannan-Quinn Criterion	-148.1166	Average Mean Squared Error	3.02E-06
Root Mean Squared Error	0.001776	Sum of Squared Residuals	5.04E-05		
Average Mean Squared Error	3.02E-06	Root Mean Squared Error	0.001776		
		Average Mean Squared Error	3.02E-06		

Coal Fatality Incident Rate, Automatic Trend and Error, Additive Seasonal

MODEL SUMMARY

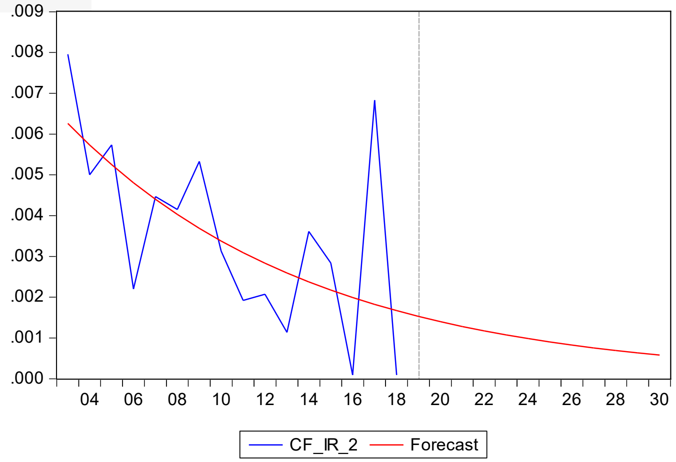
ETS Smoothing
Original series: CF_IR_2
Sample: 2003 2030
Included observations: 16
Model: A,M,A - Additive Error, Multiplicative Trend,
Additive Season (Auto E=*, T=*)
Model selection: Akaike Information Criterion
Convergence achieved on boundaries.

Parameters	
Alpha:	0.000000
Beta:	0.000000
Gamma:	0.000000

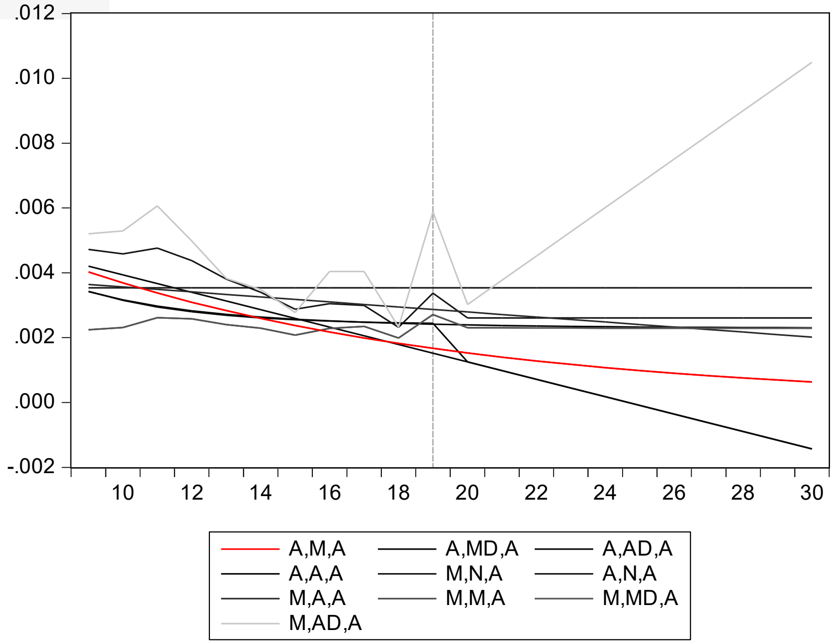
Initial Parameters	
Initial level:	0.006837
Initial trend:	0.915648
Initial state 1:	0.000000
Compact Log-likelihood	79.15721

Log-likelihood	78.63491
Akaike Information Criterion	-148.3144
Schwarz Criterion	-144.4515
Hannan-Quinn Criterion	-148.1166
Sum of Squared Residuals	5.04E-05
Root Mean Squared Error	0.001776
Average Mean Squared Error	3.02E-06

Decomposition Graph



Forecast Comparison Graph

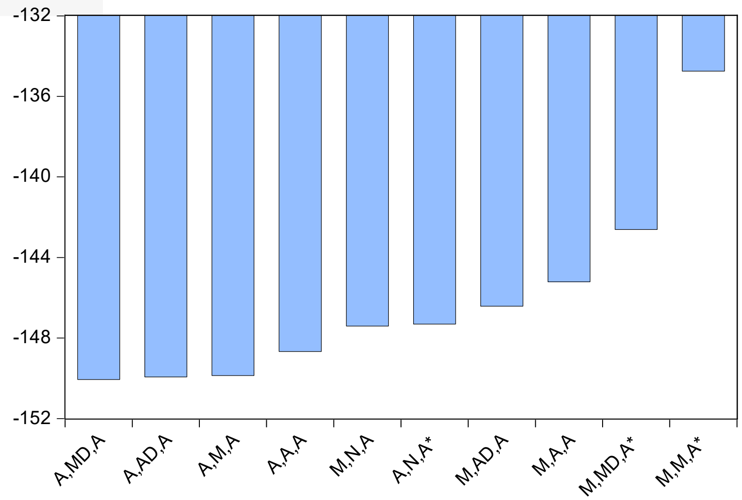


FORECAST COMPARISON TABLE

	Actuals	A,M,A[33]	A,MD,A	A,AD,A	A,A,A	M,N,A	A,N,A	M,A,A	M,M,A	M,MD,A	M,AD,A
2003	0.0080	0.0063	0.0075	0.0073	0.0055	0.0035	0.0050	0.0040	0.0042	0.0042	-0.0083
2004	0.0050	0.0057	0.0059	0.0060	0.0053	0.0035	0.0057	0.0040	0.0036	0.0036	0.0026
2005	0.0057	0.0052	0.0049	0.0050	0.0050	0.0035	0.0055	0.0039	0.0029	0.0029	0.0048
2006	0.0022	0.0048	0.0042	0.0043	0.0047	0.0035	0.0056	0.0038	0.0027	0.0027	0.0061
2007	0.0045	0.0044	0.0038	0.0038	0.0045	0.0035	0.0048	0.0037	0.0022	0.0022	0.0044
2008	0.0042	0.0040	0.0034	0.0034	0.0042	0.0035	0.0047	0.0036	0.0022	0.0022	0.0052
2009	0.0053	0.0037	0.0032	0.0032	0.0039	0.0035	0.0046	0.0036	0.0023	0.0023	0.0053
2010	0.0031	0.0034	0.0030	0.0029	0.0037	0.0035	0.0048	0.0035	0.0026	0.0026	0.0061
2011	0.0019	0.0031	0.0028	0.0028	0.0034	0.0035	0.0044	0.0034	0.0026	0.0026	0.0050
2012	0.0021	0.0028	0.0027	0.0027	0.0031	0.0035	0.0038	0.0033	0.0024	0.0024	0.0038
2013	0.0011	0.0026	0.0026	0.0026	0.0029	0.0035	0.0034	0.0033	0.0023	0.0023	0.0035
2014	0.0036	0.0024	0.0026	0.0026	0.0026	0.0035	0.0029	0.0032	0.0021	0.0021	0.0028
2015	0.0028	0.0022	0.0025	0.0025	0.0023	0.0035	0.0030	0.0031	0.0023	0.0023	0.0040
2016	9.E-05	0.0020	0.0025	0.0025	0.0021	0.0035	0.0030	0.0030	0.0023	0.0023	0.0040
2017	0.0068	0.0018	0.0024	0.0025	0.0018	0.0035	0.0023	0.0029	0.0020	0.0020	0.0023
2018	9.E-05	0.0017	0.0024	0.0024	0.0015	0.0035	0.0034	0.0029	0.0027	0.0027	0.0059
2019	NA	0.0015	0.0024	0.0013	0.0013	0.0035	0.0026	0.0028	0.0023	0.0023	0.0030
2020	NA	0.0014	0.0024	0.0010	0.0010	0.0035	0.0026	0.0027	0.0023	0.0023	0.0038
2021	NA	0.0013	0.0024	0.0007	0.0007	0.0035	0.0026	0.0026	0.0023	0.0023	0.0045
2022	NA	0.0012	0.0023	0.0004	0.0004	0.0035	0.0026	0.0026	0.0023	0.0023	0.0053
2023	NA	0.0011	0.0023	0.0002	0.0002	0.0035	0.0026	0.0025	0.0023	0.0023	0.0060
2024	NA	0.0010	0.0023	-9.E-05	-9.E-05	0.0035	0.0026	0.0024	0.0023	0.0023	0.0068
2025	NA	0.0009	0.0023	-0.0004	-0.0004	0.0035	0.0026	0.0023	0.0023	0.0023	0.0075
2026	NA	0.0008	0.0023	-0.0006	-0.0006	0.0035	0.0026	0.0022	0.0023	0.0023	0.0083
2027	NA	0.0008	0.0023	-0.0009	-0.0009	0.0035	0.0026	0.0022	0.0023	0.0023	0.0090
2028	NA	0.0007	0.0023	-0.0012	-0.0012	0.0035	0.0026	0.0021	0.0023	0.0023	0.0097

[33] These forecasts are the same as those from the A,M,N model

AIC COMPARISON GRAPH



LL (log-Likelihood) -Based Comparison Table

Model	Compact LL	Likelihood	AIC*	BIC	HQ	AMSE
A,MD, A	81.0282	80.5059	-150.056	-145.421	-149.819	2.5E-06
A,AD, A	80.9669	80.4445	-149.934	-145.298	-149.696	NA
A,M,A	79.9321	79.4098	-149.864	-146.001	-149.666	2.7E-06
A,A,A	79.3340	78.8116	-148.668	-144.805	-148.470	2.8E-06
M,N,A	76.7056	76.1833	-147.411	-145.094	-147.293	3.5E-06
A,N,A *	76.6563	76.1340	-147.313	-144.995	-147.194	4.0E-06
M,AD, A	79.2098	78.6875	-146.420	-141.784	-146.182	NA

M,A,A	77.6014	77.0791	-145.203	-141.340	-145.005	3.0E-06
M,MD,A*	77.3043	76.7819	-142.609	-137.973	-142.371	7.2E-06
M,M,A*	72.3734	71.8511	-134.747	-130.884	-134.549	5.9E-06

*3 models failed to converge

Coal Fatality Incident Rate, Automatic Trend and Error, Multiplicative Seasonal

MODEL SUMMARY

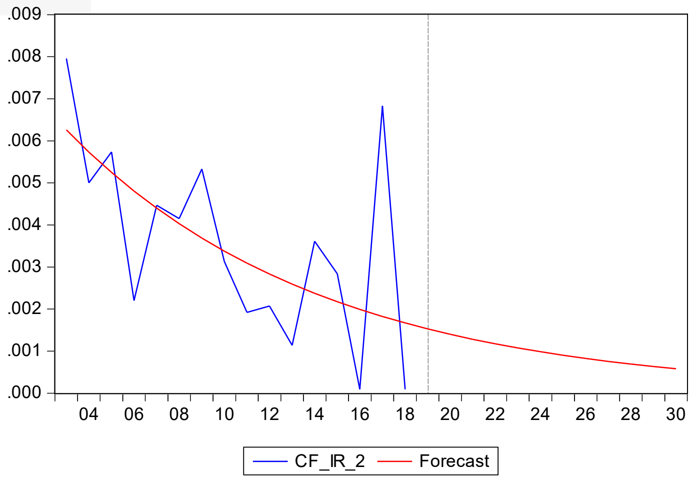
ETS Smoothing
Original series: CF_IR_2
Sample: 2003 2030
Included observations: 16
Model: A,M,M - Additive Error, Multiplicative Trend,
Multiplicative Season (Auto E=*, T=*)
Model selection: Akaike Information Criterion
Convergence achieved on boundaries.

Parameters	
Alpha:	0.000000
Beta:	0.000000
Gamma:	0.000000

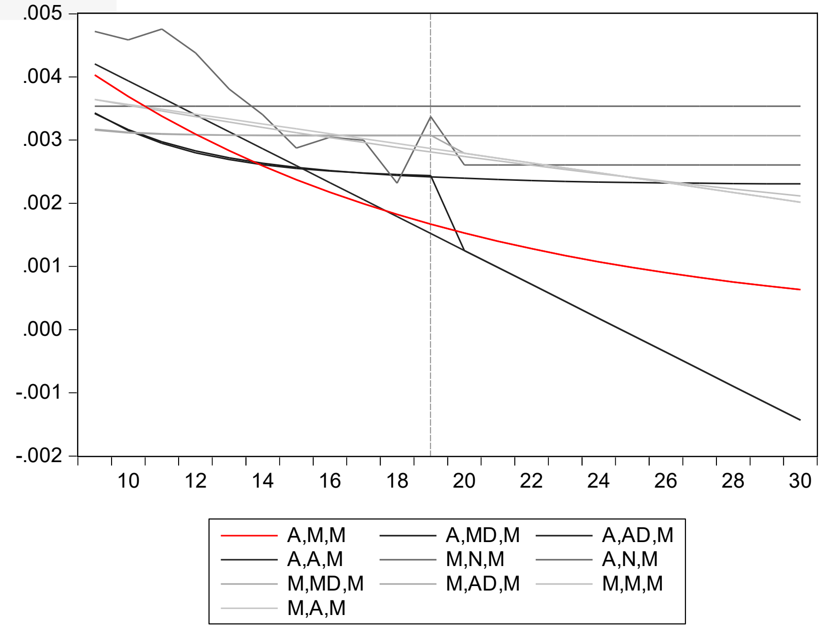
Initial Parameters	
Initial level:	0.006837
Initial trend:	0.915648
Initial state 1:	1.000000

Compact Log-likelihood	79.15721
Log-likelihood	78.63491
Akaike Information Criterion	-148.3144
Schwarz Criterion	-144.4515
Hannan-Quinn Criterion	-148.1166
Sum of Squared Residuals	5.04E-05
Root Mean Squared Error	0.001776
Average Mean Squared Error	3.02E-06

Decomposition Graph



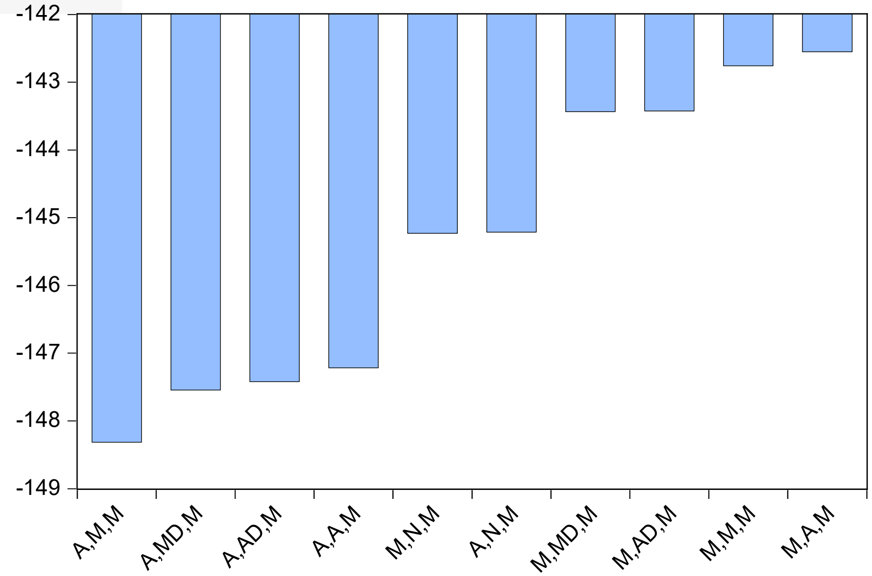
Forecast Comparison Graph



FORECAST COMPARISON TABLE

	Actuals	A,M,M	A,MD,M	A,AD,M	A,A,M	M,N,M	A,N,M	M,MD,M	M,AD,M	M,M,M	M,A,M
2003	0.0080	0.0063	0.0075	0.0073	0.0055	0.0035	0.0050	0.0062	0.0061	0.0041	0.0040
2004	0.0050	0.0057	0.0059	0.0060	0.0053	0.0035	0.0057	0.0045	0.0046	0.0040	0.0040
2005	0.0057	0.0052	0.0049	0.0050	0.0050	0.0035	0.0055	0.0038	0.0038	0.0039	0.0039
2006	0.0022	0.0048	0.0042	0.0043	0.0047	0.0035	0.0056	0.0034	0.0034	0.0038	0.0038
2007	0.0045	0.0044	0.0038	0.0038	0.0045	0.0035	0.0048	0.0033	0.0032	0.0037	0.0037
2008	0.0042	0.0040	0.0034	0.0034	0.0042	0.0035	0.0047	0.0032	0.0032	0.0036	0.0036
2009	0.0053	0.0037	0.0032	0.0032	0.0039	0.0035	0.0046	0.0031	0.0031	0.0036	0.0036
2010	0.0031	0.0034	0.0030	0.0029	0.0037	0.0035	0.0048	0.0031	0.0031	0.0035	0.0035
2011	0.0019	0.0031	0.0028	0.0028	0.0034	0.0035	0.0044	0.0031	0.0031	0.0034	0.0034
2012	0.0021	0.0028	0.0027	0.0027	0.0031	0.0035	0.0038	0.0031	0.0031	0.0033	0.0033
2013	0.0011	0.0026	0.0026	0.0026	0.0029	0.0035	0.0034	0.0031	0.0031	0.0032	0.0033
2014	0.0036	0.0024	0.0026	0.0026	0.0026	0.0035	0.0029	0.0031	0.0031	0.0031	0.0032
2015	0.0028	0.0022	0.0025	0.0025	0.0023	0.0035	0.0030	0.0031	0.0031	0.0030	0.0031
2016	9.E-05	0.0020	0.0025	0.0025	0.0021	0.0035	0.0030	0.0031	0.0031	0.0030	0.0030
2017	0.0068	0.0018	0.0024	0.0025	0.0018	0.0035	0.0023	0.0031	0.0031	0.0029	0.0029
2018	9.E-05	0.0017	0.0024	0.0024	0.0015	0.0035	0.0034	0.0031	0.0031	0.0028	0.0029
2019	NA	0.0015	0.0024	0.0013	0.0013	0.0035	0.0026	0.0031	0.0028	0.0027	0.0028
2020	NA	0.0014	0.0024	0.0010	0.0010	0.0035	0.0026	0.0031	0.0027	0.0027	0.0027
2021	NA	0.0013	0.0024	0.0007	0.0007	0.0035	0.0026	0.0031	0.0026	0.0026	0.0026
2022	NA	0.0012	0.0023	0.0004	0.0004	0.0035	0.0026	0.0031	0.0026	0.0025	0.0026
2023	NA	0.0011	0.0023	0.0002	0.0002	0.0035	0.0026	0.0031	0.0025	0.0025	0.0025
2024	NA	0.0010	0.0023	-9.E-05	-9.E-05	0.0035	0.0026	0.0031	0.0024	0.0024	0.0024
2025	NA	0.0009	0.0023	-0.0004	-0.0004	0.0035	0.0026	0.0031	0.0023	0.0023	0.0023
2026	NA	0.0008	0.0023	-0.0006	-0.0006	0.0035	0.0026	0.0031	0.0022	0.0023	0.0022
2027	NA	0.0008	0.0023	-0.0009	-0.0009	0.0035	0.0026	0.0031	0.0022	0.0022	0.0022
2028	NA	0.0007	0.0023	-0.0012	-0.0012	0.0035	0.0026	0.0031	0.0021	0.0022	0.0021

AIC COMPARISON GRAPH



LL-Based Comparison Table

Model	Compact LL	Likelihood	AIC*	BIC	HQ	AMSE
A,M,M	79.1572	78.6349	-148.314	-144.451	-148.117	3.0E-06
A,MD, M	79.7727	79.2504	-147.545	-142.910	-147.308	2.9E-06
A,AD, M	79.7107	79.1884	-147.421	-142.786	-147.184	NA
A,A,M	78.6083	78.0860	-147.217	-143.354	-147.019	3.1E-06
M,N,M	75.6145	75.0922	-145.229	-142.911	-145.110	4.0E-06
A,N,M	75.6075	75.0852	-145.215	-142.897	-145.096	4.5E-06
M,MD,	77.7172	77.1949	-143.434	-138.799	-143.197	3.5E-06

M							
M	M,AD,	77.7121	77.1898	-143.424	-138.789	-143.187	NA
M	M,M,	76.3794	75.8571	-142.759	-138.896	-142.561	3.4E-06
	M,A,M	76.2754	75.7531	-142.551	-138.688	-142.353	3.5E-06

Coal Fatality Incident Rate, Automatic Trend and Error, No Seasonal

MODEL SUMMARY

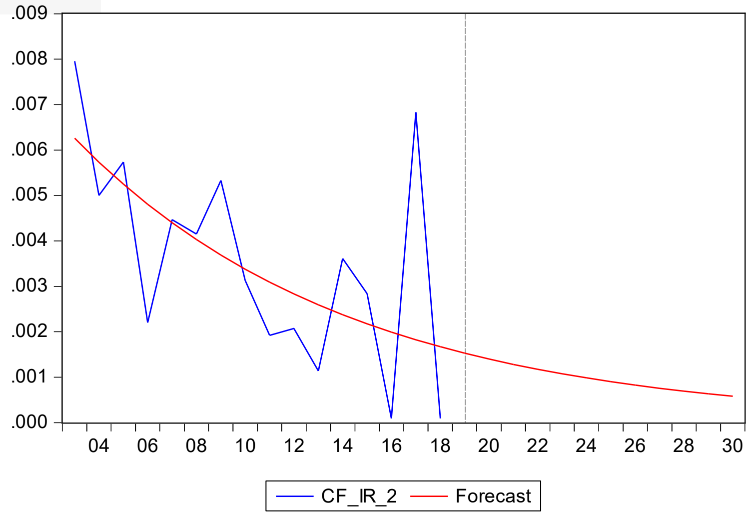
ETS Smoothing
Original series: CF_IR_2
Sample: 2003 2030
Included observations: 16
Model: A,M,N - Additive Error, Multiplicative Trend,
No Season (Auto E=*, T=*)
Model selection: Akaike Information Criterion
Convergence achieved on boundaries.

Parameters	
Alpha:	0.000000
Beta:	0.000000

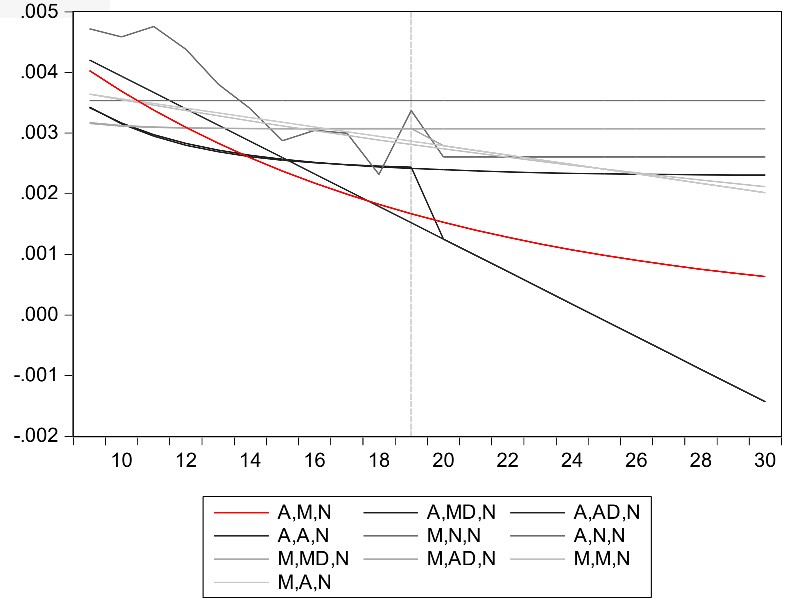
Initial Parameters	
Initial level:	0.006837
Initial trend:	0.915648

Compact Log-likelihood	79.15721
Log-likelihood	78.63491
Akaike Information Criterion	-150.3144
Schwarz Criterion	-147.2241
Hannan-Quinn Criterion	-150.1562
Sum of Squared Residuals	5.04E-05
Root Mean Squared Error	0.001776
Average Mean Squared Error	3.02E-06

Decomposition Graph



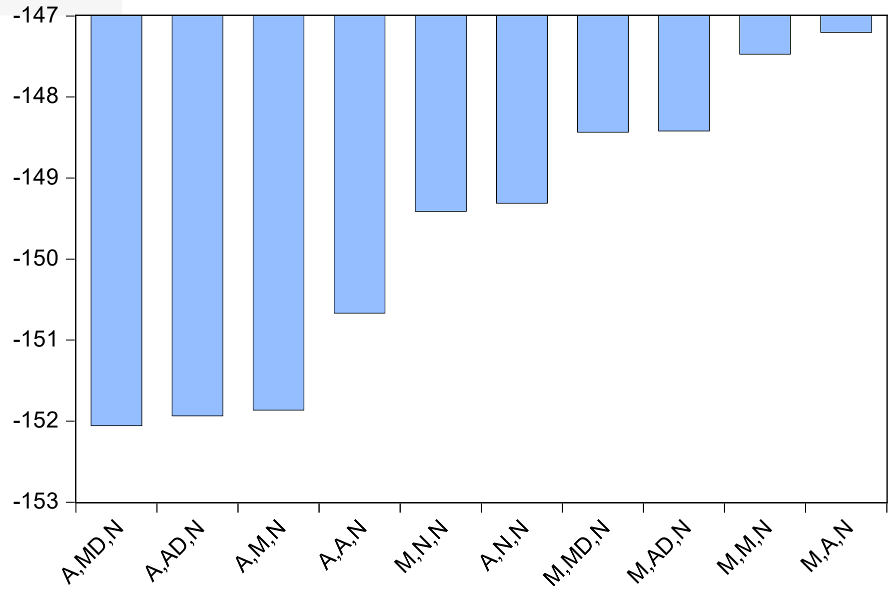
Forecast Comparison Graph



FORECAST COMPARISON TABLE

	Actuals	A,M,N	A,MD,N	A,AD,N	A,A,N	M,N,N	A,N,N	M,MD,N	M,AD,N	M,M,N	M,A,N
2003	0.0080	0.0063	0.0075	0.0073	0.0055	0.0035	0.0050	0.0062	0.0061	0.0041	0.0040
2004	0.0050	0.0057	0.0059	0.0060	0.0053	0.0035	0.0057	0.0045	0.0046	0.0040	0.0040
2005	0.0057	0.0052	0.0049	0.0050	0.0050	0.0035	0.0055	0.0038	0.0038	0.0039	0.0039
2006	0.0022	0.0048	0.0042	0.0043	0.0047	0.0035	0.0056	0.0034	0.0034	0.0038	0.0038
2007	0.0045	0.0044	0.0038	0.0038	0.0045	0.0035	0.0048	0.0033	0.0032	0.0037	0.0037
2008	0.0042	0.0040	0.0034	0.0034	0.0042	0.0035	0.0047	0.0032	0.0032	0.0036	0.0036
2009	0.0053	0.0037	0.0032	0.0032	0.0039	0.0035	0.0046	0.0031	0.0031	0.0036	0.0036
2010	0.0031	0.0034	0.0030	0.0029	0.0037	0.0035	0.0048	0.0031	0.0031	0.0035	0.0035
2011	0.0019	0.0031	0.0028	0.0028	0.0034	0.0035	0.0044	0.0031	0.0031	0.0034	0.0034
2012	0.0021	0.0028	0.0027	0.0027	0.0031	0.0035	0.0038	0.0031	0.0031	0.0033	0.0033
2013	0.0011	0.0026	0.0026	0.0026	0.0029	0.0035	0.0034	0.0031	0.0031	0.0032	0.0033
2014	0.0036	0.0024	0.0026	0.0026	0.0026	0.0035	0.0029	0.0031	0.0031	0.0031	0.0032
2015	0.0028	0.0022	0.0025	0.0025	0.0023	0.0035	0.0030	0.0031	0.0031	0.0030	0.0031
2016	9.E-05	0.0020	0.0025	0.0025	0.0021	0.0035	0.0030	0.0031	0.0031	0.0030	0.0030
2017	0.0068	0.0018	0.0024	0.0025	0.0018	0.0035	0.0023	0.0031	0.0031	0.0029	0.0029
2018	9.E-05	0.0017	0.0024	0.0024	0.0015	0.0035	0.0034	0.0031	0.0031	0.0028	0.0029
2019	NA	0.0015	0.0024	0.0013	0.0013	0.0035	0.0026	0.0031	0.0028	0.0027	0.0028
2020	NA	0.0014	0.0024	0.0010	0.0010	0.0035	0.0026	0.0031	0.0027	0.0027	0.0027
2021	NA	0.0013	0.0024	0.0007	0.0007	0.0035	0.0026	0.0031	0.0026	0.0026	0.0026
2022	NA	0.0012	0.0023	0.0004	0.0004	0.0035	0.0026	0.0031	0.0026	0.0025	0.0026
2023	NA	0.0011	0.0023	0.0002	0.0002	0.0035	0.0026	0.0031	0.0025	0.0025	0.0025
2024	NA	0.0010	0.0023	-9.E-05	-9.E-05	0.0035	0.0026	0.0031	0.0024	0.0024	0.0024
2025	NA	0.0009	0.0023	-0.0004	-0.0004	0.0035	0.0026	0.0031	0.0023	0.0023	0.0023
2026	NA	0.0008	0.0023	-0.0006	-0.0006	0.0035	0.0026	0.0031	0.0022	0.0023	0.0022
2027	NA	0.0008	0.0023	-0.0009	-0.0009	0.0035	0.0026	0.0031	0.0022	0.0022	0.0022
2028	NA	0.0007	0.0023	-0.0012	-0.0012	0.0035	0.0026	0.0031	0.0021	0.0022	0.0021

AIC COMPARISON GRAPH



LL-Based Comparison Table

Model	Compact LL	Likelihood	AIC*	BIC	HQ	AMSE
A,MD,N	81.0282	80.5059	-152.056	-148.193	-151.859	2.5E-06
A,AD,N	80.9669	80.4446	-151.934	-148.071	-151.736	NA
A,M,N	79.9321	79.4098	-151.864	-148.774	-151.706	2.7E-06
A,A,N	79.3340	78.8116	-150.668	-147.578	-150.510	2.8E-06
M,N,N	76.7056	76.1833	-149.411	-147.866	-149.332	3.5E-06
A,N,N	76.6563	76.1340	-149.313	-147.767	-149.234	4.0E-06

M,MD,N	79.2177	78.6954	-148.435	-144.573	-148.238	2.9E-06
M,AD,N	79.2098	78.6875	-148.420	-144.557	-148.222	NA
M,M,N	77.7358	77.2134	-147.472	-144.381	-147.313	2.9E-06
M,A,N	77.6014	77.0791	-147.203	-144.113	-147.045	3.0E-06

Summary of Model Selection Outputs, Coal Nonfatal Days Lost Incident Rate

The fully automatic method of ETS fails automatic selection of seasonality as the time series is too short. Manually executing the ETS procedure with the seasonality set to additive, multiplicative, and none start with different estimated parameters but conclude modeling with the same residuals and errors. The additive and no seasonal approach converged on a solution after six iterations each while the multiplicative seasonality converged at the boundary. Given the AIC difference is due to the number of parameters, the simplest model, A,N,N is the model selected to represent the NFDL incident forecast.

ETS Smoothing
Original series: CNFDL_IR
Sample: 2003 2018
Included observations: 16
Model: A,N,A - Additive Error, No Trend, Additive Season (Auto E=*, T=*)
Model selection: Akaike Information Criterion
Convergence achieved after 6 iterations

Parameters	
Alpha:	0.493041
Gamma:	0.183923

Initial Parameters	
Initial level:	0.035224
Initial state 1:	0.000000

ETS Smoothing
Original series: CNFDL_IR
Sample: 2003 2018
Included observations: 16
Model: A,N,M - Additive Error, No Trend, Multiplicative Season (Auto E=*, T=*)
Model selection: Akaike Information Criterion
Convergence achieved on boundaries.

Parameters	
Alpha:	0.676964
Gamma:	0.000000

Initial Parameters	
Initial level:	0.035224

ETS Smoothing
Original series: CNFDL_IR
Sample: 2003 2018
Included observations: 16
Model: A,N,N - Additive Error, No Trend, No Season (Simple exponential model) (Auto E= *, T=*)
Model selection: Akaike Information Criterion
Convergence achieved after 6 iterations

Parameters	
Alpha:	0.676964

Initial Parameters	
Initial level:	0.035224

Compact Log-likelihood	57.37729
Log-likelihood	56.85498
Akaike Information Criterion	-108.7546
Schwarz Criterion	-106.4368
Hannan-Quinn Criterion	-108.6359
Sum of Squared Residuals	0.000768
Root Mean Squared Error	0.006927
Average Mean Squared Error	6.67E-05

Initial state 1:	1.000000
Compact Log-likelihood	57.37729
Log-likelihood	56.85498
Akaike Information Criterion	-108.7546
Schwarz Criterion	-106.4368
Hannan-Quinn Criterion	-108.6359
Sum of Squared Residuals	0.000768
Root Mean Squared Error	0.006927
Average Mean Squared Error	6.67E-05

Compact Log-likelihood	57.37729
Log-likelihood	56.85498
Akaike Information Criterion	-110.7546
Schwarz Criterion	-109.2094
Hannan-Quinn Criterion	-110.6755
Sum of Squared Residuals	0.000768
Root Mean Squared Error	0.006927
Average Mean Squared Error	6.67E-05

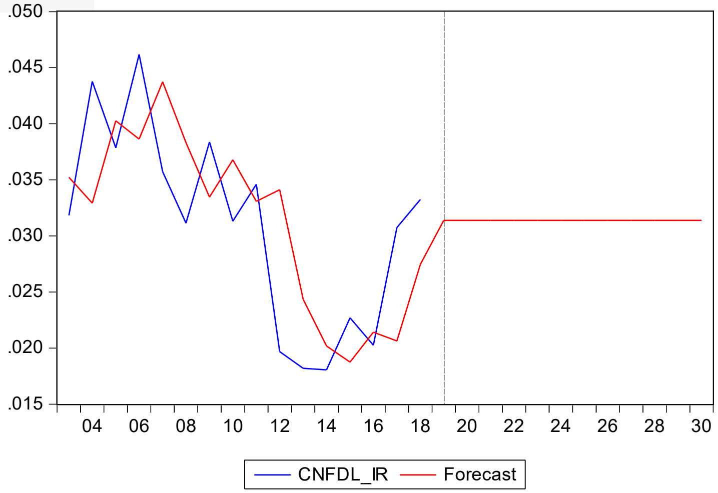
Coal NFDL, Automatic Trend and Error, Additive Seasonal

ESTIMATION OUTPUT

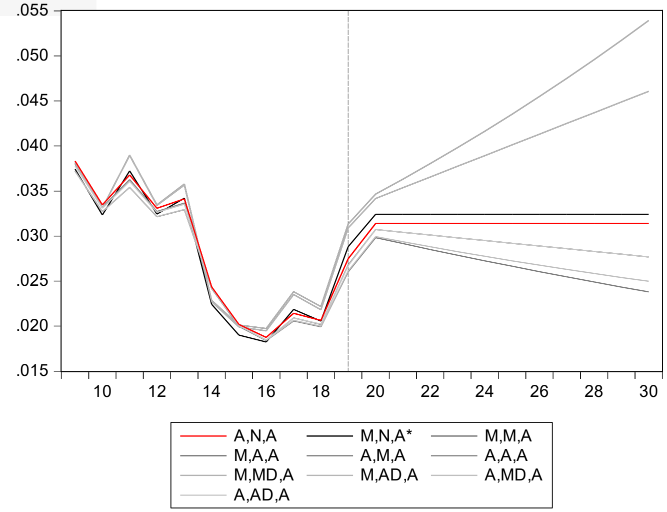
ETS Smoothing
Original series: CNFDL_IR
Sample: 2003 2018
Included observations: 16
Model: A,N,A - Additive Error, No Trend, Additive
Season (Auto E=*, T=*)
Model selection: Akaike Information Criterion
Convergence achieved after 6 iterations

Parameters	
Alpha:	0.493041
Gamma:	0.183923
Initial Parameters	
Initial level:	0.035224
Initial state 1:	0.000000
Compact Log-likelihood	57.37729
Log-likelihood	56.85498
Akaike Information Criterion	-108.7546
Schwarz Criterion	-106.4368
Hannan-Quinn Criterion	-108.6359
Sum of Squared Residuals	0.000768
Root Mean Squared Error	0.006927
Average Mean Squared Error	6.67E-05

Decomposition Graph



Forecast Comparison Graph

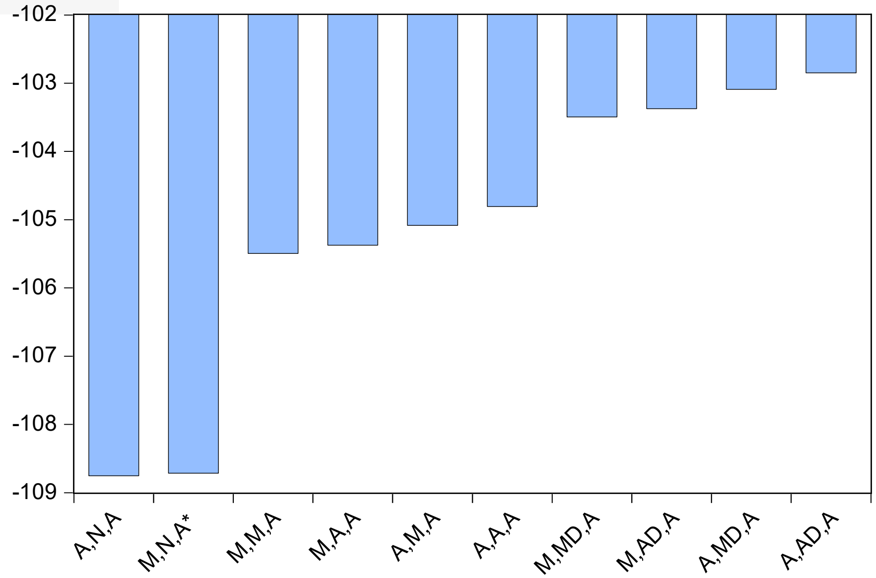


FORECAST COMPARISON TABLE

	Actuals	A,N,A	M,N,A*	M,M,A	M,A,A	A,M,A	A,A,A	M,MD,A	M,AD,A	A,MD,A	A,AD,A
2003	0.0318	0.0352	0.0328	0.0316	0.0316	0.0361	0.0356	0.0316	0.0316	0.0362	0.0358
2004	0.0438	0.0329	0.0320	0.0328	0.0330	0.0327	0.0328	0.0328	0.0330	0.0327	0.0327
2005	0.0379	0.0403	0.0415	0.0436	0.0437	0.0387	0.0397	0.0436	0.0437	0.0386	0.0393
2006	0.0462	0.0386	0.0386	0.0396	0.0397	0.0373	0.0382	0.0396	0.0397	0.0372	0.0378
2007	0.0357	0.0437	0.0447	0.0465	0.0466	0.0419	0.0431	0.0465	0.0466	0.0418	0.0427
2008	0.0311	0.0383	0.0374	0.0381	0.0382	0.0372	0.0380	0.0381	0.0382	0.0372	0.0378
2009	0.0384	0.0335	0.0323	0.0331	0.0331	0.0327	0.0332	0.0331	0.0331	0.0327	0.0331
2010	0.0313	0.0368	0.0372	0.0390	0.0390	0.0354	0.0363	0.0390	0.0390	0.0354	0.0361
2011	0.0346	0.0331	0.0324	0.0334	0.0334	0.0321	0.0327	0.0334	0.0334	0.0321	0.0326
2012	0.0197	0.0341	0.0342	0.0358	0.0357	0.0329	0.0337	0.0358	0.0357	0.0329	0.0335
2013	0.0182	0.0243	0.0224	0.0229	0.0227	0.0242	0.0242	0.0229	0.0227	0.0242	0.0243
2014	0.0181	0.0202	0.0190	0.0201	0.0199	0.0200	0.0200	0.0201	0.0199	0.0201	0.0201
2015	0.0227	0.0187	0.0182	0.0197	0.0195	0.0184	0.0184	0.0197	0.0195	0.0184	0.0185
2016	0.0203	0.0214	0.0218	0.0238	0.0235	0.0206	0.0209	0.0238	0.0235	0.0206	0.0209
2017	0.0307	0.0206	0.0206	0.0222	0.0218	0.0199	0.0202	0.0222	0.0218	0.0200	0.0202
2018	0.0333	0.0275	0.0288	0.0313	0.0309	0.0260	0.0268	0.0313	0.0309	0.0261	0.0267
2019	NA	0.0314	0.0324	0.0347	0.0342	0.0298	0.0307	0.0347	0.0342	0.0299	0.0307
2020	NA	0.0314	0.0324	0.0363	0.0354	0.0292	0.0304	0.0363	0.0354	0.0294	0.0304
2021	NA	0.0314	0.0324	0.0380	0.0366	0.0285	0.0301	0.0380	0.0366	0.0288	0.0301
2022	NA	0.0314	0.0324	0.0398	0.0377	0.0279	0.0298	0.0398	0.0377	0.0283	0.0298
2023	NA	0.0314	0.0324	0.0416	0.0389	0.0273	0.0295	0.0416	0.0389	0.0278	0.0295
2024	NA	0.0314	0.0324	0.0435	0.0401	0.0266	0.0292	0.0435	0.0401	0.0272	0.0292
2025	NA	0.0314	0.0324	0.0455	0.0413	0.0260	0.0289	0.0455	0.0413	0.0268	0.0289
2026	NA	0.0314	0.0324	0.0475	0.0425	0.0255	0.0286	0.0475	0.0425	0.0263	0.0286
2027	NA	0.0314	0.0324	0.0496	0.0437	0.0249	0.0283	0.0496	0.0437	0.0258	0.0283
2028	NA	0.0314	0.0324	0.0517	0.0449	0.0243	0.0280	0.0517	0.0449	0.0254	0.0280

*1 model failed to converge

AIC COMPARISON GRAPH



LL-Based Comparison Table

Model	Compact LL	Likelihood	AIC*	BIC	HQ	AMSE
A,N, A	57.3773	56.8550	-108.755	-106.437	-108.636	6.7E-05
M,N, A*	57.3570	56.8347	-108.714	-106.396	-108.595	6.9E-05
M,M, A	57.7480	57.2257	-105.496	-101.633	-105.298	8.2E-05
M,A, A	57.6867	57.1644	-105.373	-101.511	-105.176	8.2E-05
A,M,	57.5412	57.0189	-105.082	-101.219	-104.885	6.0E-05

A						
A,A,A	57.4045	56.8822	-104.809	-100.946	-104.611	6.5E-05
M,MD,A	57.7480	57.2257	-103.496	-98.8605	-103.259	8.2E-05
M,AD,A	57.6867	57.1644	-103.373	-98.7379	-103.136	8.2E-05
A,MD,A	57.5442	57.0219	-103.088	-98.4529	-102.851	6.0E-05
A,AD,A	57.4244	56.9021	-102.849	-98.2133	-102.611	NA

*1 model failed to converge

Coal NFDL, Automatic Trend and Error, Multiplicative Seasonal

ESTIMATION OUTPUT

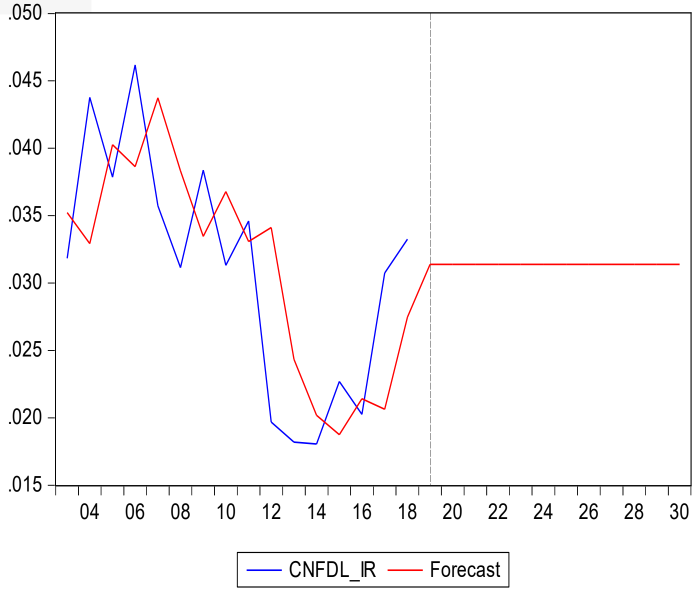
ETS Smoothing
Original series: CNFDL_IR
Sample: 2003 2018
Included observations: 16
Model: A,N,M - Additive Error, No Trend,
Multiplicative Season (Auto E=*, T=*)
Model selection: Akaike Information Criterion
Convergence achieved on boundaries.

Parameters	
Alpha:	0.676964
Gamma:	0.000000

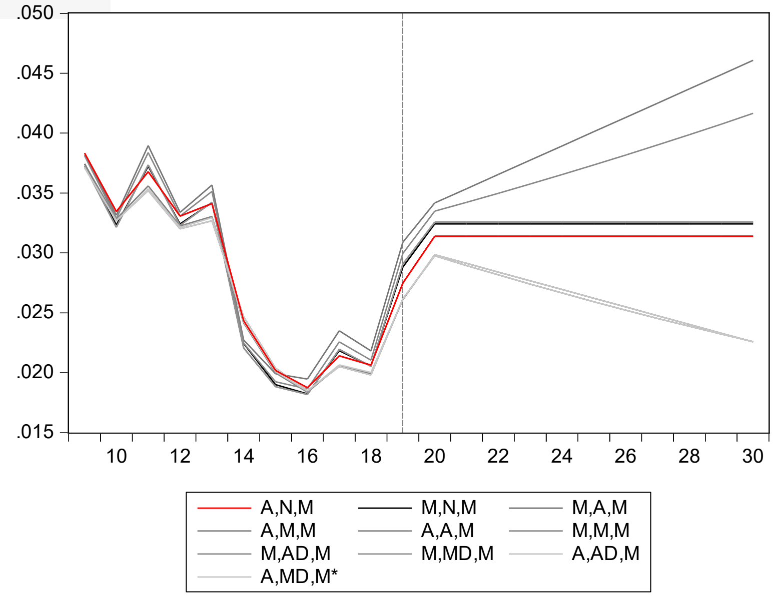
Initial Parameters

Initial level:	0.035224
Initial state 1:	1.000000
Compact Log-likelihood	57.37729
Log-likelihood	56.85498
Akaike Information Criterion	-108.7546
Schwarz Criterion	-106.4368
Hannan-Quinn Criterion	-108.6359
Sum of Squared Residuals	0.000768
Root Mean Squared Error	0.006927
Average Mean Squared Error	6.67E-05

Decomposition Graph



Forecast Comparison Graph

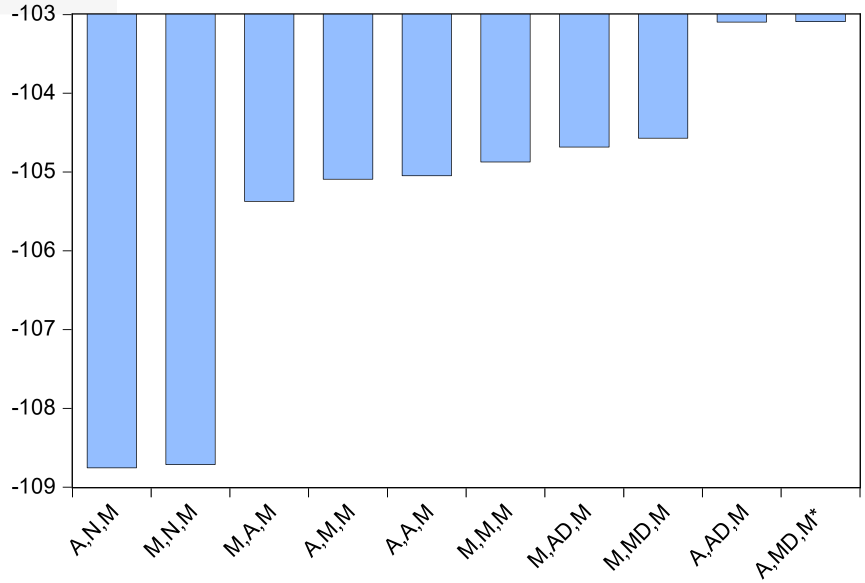


FORECAST COMPARISON TABLE

	Actuals	A,N,M	M,N,M	M,A,M	A,M,M	A,A,M	M,M,M	M,AD,M	M,MD,M	A,AD,M	A,MD,M *
2003	0.0318	0.0352	0.0328	0.0316	0.0365	0.0360	0.0321	0.0304	0.0306	0.0362	0.0365
2004	0.0438	0.0329	0.0320	0.0330	0.0329	0.0328	0.0326	0.0410	0.0402	0.0326	0.0329
2005	0.0379	0.0403	0.0415	0.0437	0.0386	0.0390	0.0430	0.0436	0.0446	0.0385	0.0386
2006	0.0462	0.0386	0.0386	0.0397	0.0371	0.0376	0.0395	0.0388	0.0391	0.0372	0.0371
2007	0.0357	0.0437	0.0447	0.0466	0.0416	0.0422	0.0462	0.0450	0.0450	0.0417	0.0416
2008	0.0311	0.0383	0.0374	0.0382	0.0371	0.0374	0.0381	0.0372	0.0373	0.0371	0.0371
2009	0.0384	0.0335	0.0323	0.0331	0.0327	0.0328	0.0329	0.0321	0.0321	0.0326	0.0327
2010	0.0313	0.0368	0.0372	0.0390	0.0352	0.0356	0.0384	0.0374	0.0373	0.0354	0.0352
2011	0.0346	0.0331	0.0324	0.0334	0.0320	0.0322	0.0331	0.0323	0.0323	0.0321	0.0320
2012	0.0197	0.0341	0.0342	0.0357	0.0327	0.0330	0.0351	0.0342	0.0342	0.0329	0.0327
2013	0.0182	0.0243	0.0224	0.0227	0.0247	0.0241	0.0225	0.0221	0.0221	0.0242	0.0247
2014	0.0181	0.0202	0.0190	0.0199	0.0204	0.0200	0.0192	0.0188	0.0188	0.0201	0.0204
2015	0.0227	0.0187	0.0182	0.0195	0.0185	0.0184	0.0186	0.0182	0.0182	0.0185	0.0185
2016	0.0203	0.0214	0.0218	0.0235	0.0205	0.0206	0.0226	0.0220	0.0219	0.0207	0.0205
2017	0.0307	0.0206	0.0206	0.0218	0.0198	0.0199	0.0211	0.0205	0.0205	0.0200	0.0198
2018	0.0333	0.0275	0.0288	0.0309	0.0262	0.0261	0.0300	0.0291	0.0291	0.0261	0.0262
2019	NA	0.0314	0.0324	0.0342	0.0298	0.0299	0.0335	0.0326	0.0326	0.0299	0.0298
2020	NA	0.0314	0.0324	0.0354	0.0289	0.0291	0.0342	0.0326	0.0326	0.0291	0.0289
2021	NA	0.0314	0.0324	0.0366	0.0282	0.0284	0.0350	0.0326	0.0326	0.0284	0.0282
2022	NA	0.0314	0.0324	0.0377	0.0274	0.0277	0.0358	0.0326	0.0326	0.0277	0.0274
2023	NA	0.0314	0.0324	0.0389	0.0267	0.0269	0.0365	0.0326	0.0326	0.0269	0.0267
2024	NA	0.0314	0.0324	0.0401	0.0259	0.0262	0.0373	0.0326	0.0326	0.0262	0.0259
2025	NA	0.0314	0.0324	0.0413	0.0252	0.0255	0.0382	0.0326	0.0326	0.0255	0.0252
2026	NA	0.0314	0.0324	0.0425	0.0245	0.0248	0.0390	0.0326	0.0326	0.0248	0.0245
2027	NA	0.0314	0.0324	0.0437	0.0239	0.0240	0.0399	0.0326	0.0326	0.0240	0.0239
2028	NA	0.0314	0.0324	0.0449	0.0232	0.0233	0.0407	0.0326	0.0326	0.0233	0.0232

*1 model failed to converge

AIC COMPARISON GRAPH



LL-Based Comparison Table

Model	Compact LL	Likelihood	AIC*	BIC	HQ	AMSE
A,N,M	57.3773	56.8550	-108.755	-106.437	-108.636	6.7E-05
M,N,M	57.3570	56.8347	-108.714	-106.396	-108.595	6.9E-05
M,A,M	57.6867	57.1644	-105.373	-101.511	-105.176	8.2E-05
A,M,M	57.5454	57.0231	-105.091	-101.228	-104.893	5.9E-05
A,A,M	57.5233	57.0010	-105.047	-101.184	-104.849	6.1E-05
M,M,M	57.4367	56.9144	-104.873	-101.011	-104.676	7.9E-05
M,AD,M	58.3412	57.8189	-104.682	-100.047	-104.445	0.00073

M,MD, M	58.2853	57.7630	-104.571	-99.9350	-104.333	0.00106
A,AD, M	57.5487	57.0264	-103.097	-98.4619	-102.860	NA
A,MD, M*	57.5454	57.0231	-103.091	-98.4552	-102.853	5.9E-05

*1 model failed to converge

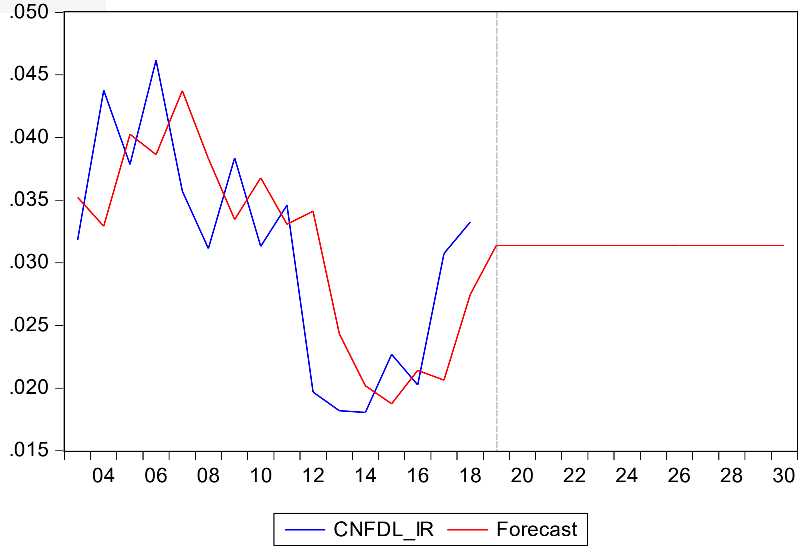
Coal NFDL, Automatic Trend and Error, No Seasonal

ESTIMATION OUTPUT

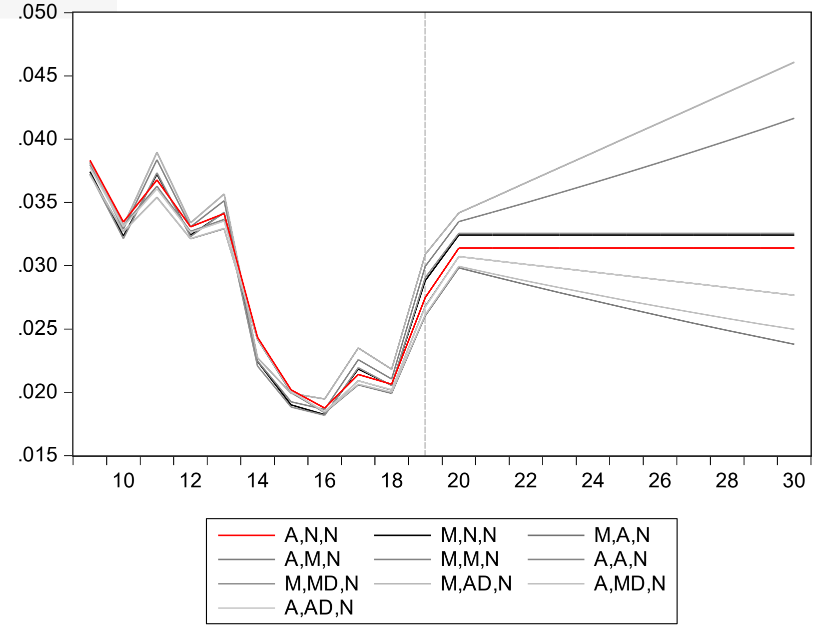
ETS Smoothing
Original series: CNFDL_IR
Sample: 2003 2018
Included observations: 16
Model: A,N,N - Additive Error, No Trend, No
Season (Simple exponential model) (Auto E=
, T=)
Model selection: Akaike Information Criterion
Convergence achieved after 6 iterations

Parameters	
Alpha:	0.676964
Initial Parameters	
Initial level:	0.035224
Compact Log-likelihood	57.37729
Log-likelihood	56.85498
Akaike Information Criterion	-110.7546
Schwarz Criterion	-109.2094
Hannan-Quinn Criterion	-110.6755
Sum of Squared Residuals	0.000768
Root Mean Squared Error	0.006927
Average Mean Squared Error	6.67E-05

Decomposition Graph



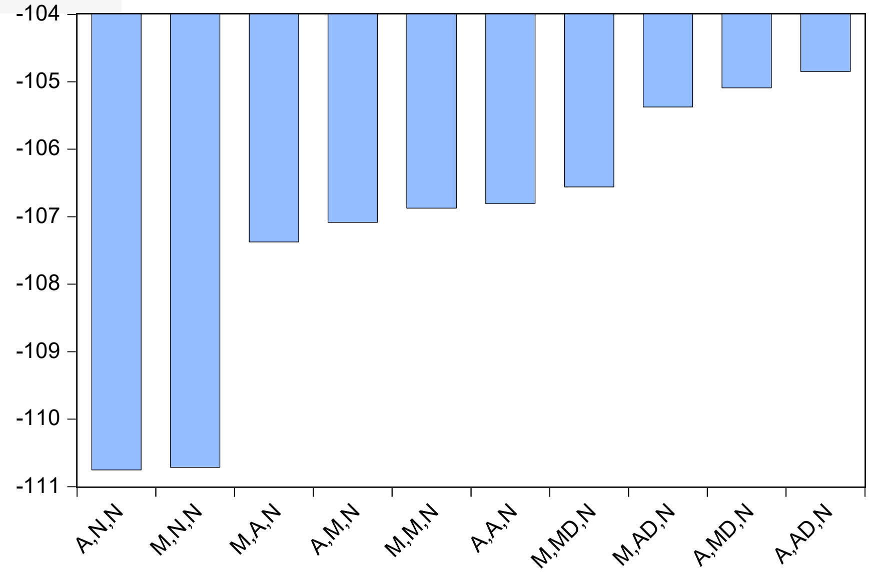
Forecast Comparison Graph



FORECAST COMPARISON TABLE

	Actuals	A,N,N	M,N,N	M,A,N	A,M,N	M,M,N	A,A,N	M,MD,N	M,AD,N	A,MD,N	A,AD,N
2003	0.0318	0.0352	0.0328	0.0316	0.0361	0.0321	0.0356	0.0306	0.0316	0.0362	0.0358
2004	0.0438	0.0329	0.0320	0.0330	0.0327	0.0326	0.0328	0.0402	0.0330	0.0327	0.0327
2005	0.0379	0.0403	0.0415	0.0437	0.0387	0.0430	0.0397	0.0445	0.0437	0.0386	0.0393
2006	0.0462	0.0386	0.0386	0.0397	0.0373	0.0395	0.0382	0.0391	0.0397	0.0372	0.0378
2007	0.0357	0.0437	0.0447	0.0466	0.0419	0.0462	0.0431	0.0450	0.0466	0.0418	0.0427
2008	0.0311	0.0383	0.0374	0.0382	0.0372	0.0381	0.0380	0.0373	0.0382	0.0372	0.0378
2009	0.0384	0.0335	0.0323	0.0331	0.0327	0.0329	0.0332	0.0321	0.0331	0.0327	0.0331
2010	0.0313	0.0368	0.0372	0.0390	0.0354	0.0384	0.0363	0.0373	0.0390	0.0354	0.0361
2011	0.0346	0.0331	0.0324	0.0334	0.0321	0.0331	0.0327	0.0323	0.0334	0.0321	0.0326
2012	0.0197	0.0341	0.0342	0.0357	0.0329	0.0351	0.0337	0.0342	0.0357	0.0329	0.0335
2013	0.0182	0.0243	0.0224	0.0227	0.0242	0.0225	0.0242	0.0221	0.0227	0.0242	0.0243
2014	0.0181	0.0202	0.0190	0.0199	0.0200	0.0192	0.0200	0.0188	0.0199	0.0201	0.0201
2015	0.0227	0.0187	0.0182	0.0195	0.0184	0.0186	0.0184	0.0182	0.0195	0.0184	0.0185
2016	0.0203	0.0214	0.0218	0.0235	0.0206	0.0226	0.0209	0.0219	0.0235	0.0206	0.0209
2017	0.0307	0.0206	0.0206	0.0218	0.0199	0.0211	0.0202	0.0205	0.0218	0.0200	0.0202
2018	0.0333	0.0275	0.0288	0.0309	0.0260	0.0300	0.0268	0.0291	0.0309	0.0261	0.0267
2019	NA	0.0314	0.0324	0.0342	0.0298	0.0335	0.0307	0.0326	0.0342	0.0299	0.0307
2020	NA	0.0314	0.0324	0.0354	0.0292	0.0342	0.0304	0.0326	0.0354	0.0294	0.0304
2021	NA	0.0314	0.0324	0.0366	0.0285	0.0350	0.0301	0.0326	0.0366	0.0288	0.0301
2022	NA	0.0314	0.0324	0.0377	0.0279	0.0358	0.0298	0.0326	0.0377	0.0283	0.0298
2023	NA	0.0314	0.0324	0.0389	0.0273	0.0365	0.0295	0.0326	0.0389	0.0278	0.0295
2024	NA	0.0314	0.0324	0.0401	0.0266	0.0373	0.0292	0.0326	0.0401	0.0272	0.0292
2025	NA	0.0314	0.0324	0.0413	0.0260	0.0382	0.0289	0.0326	0.0413	0.0268	0.0289
2026	NA	0.0314	0.0324	0.0425	0.0255	0.0390	0.0286	0.0326	0.0425	0.0263	0.0286
2027	NA	0.0314	0.0324	0.0437	0.0249	0.0399	0.0283	0.0326	0.0437	0.0258	0.0283
2028	NA	0.0314	0.0324	0.0449	0.0243	0.0407	0.0280	0.0326	0.0449	0.0254	0.0280

AIC COMPARISON GRAPH



LL-Based Comparison Table

Model	Compact LL	Likelihood	AIC*	BIC	HQ	AMSE
A,N, N	57.3773	56.8550	-110.755	-109.209	-110.675	6.7E-05
M,N, N	57.3570	56.8347	-110.714	-109.169	-110.635	6.9E-05
M,A, N	57.6867	57.1644	-107.373	-104.283	-107.215	8.2E-05
A,M, N	57.5412	57.0189	-107.082	-103.992	-106.924	6.0E-05
M,M,	57.4367	56.9144	-106.873	-103.783	-106.715	7.9E-05

N						
A,A,N	57.4045	56.8822	-106.809	-103.719	-106.651	6.5E-05
M,MD,N	58.2787	57.7564	-106.557	-102.694	-106.360	0.00079
M,AD,N	57.6867	57.1644	-105.373	-101.511	-105.176	8.2E-05
A,MD,N	57.5442	57.0219	-105.088	-101.225	-104.891	6.0E-05
A,AD,N	57.4244	56.9021	-104.849	-100.986	-104.651	NA

Summary of Model Selection Outputs, Coal No Days Lost Incident Rate

The fully automatic method of ETS fails automatic selection of seasonality as the time series is too short. Manually executing the ETS procedure with the seasonality set to additive, multiplicative, and none start with the same initial level and trend parameters but conclude modeling with very similar residuals and errors. Given the same AIC and output errors for the additive and multiplicative seasonality, and the no seasonality model has the same squared error results, the single parameter model MMN is the model selected to represent the NDL incident forecast.

ETS Smoothing Original series: CNDL_IR Sample: 2003 2018 Included observations: 16 Model: M,M,A - Multiplicative Error, Multiplicative Trend, Additive Season (Auto E=*, T=*) Model selection: Akaike Information Criterion Convergence achieved on boundaries.	ETS Smoothing Original series: CNDL_IR Sample: 2003 2018 Included observations: 16 Model: M,M,M - Multiplicative Error, Multiplicative Trend, Multiplicative Season (Auto E=*, T=*) Model selection: Akaike Information Criterion Convergence achieved on boundaries.	ETS Smoothing Original series: CNDL_IR Sample: 2003 2018 Included observations: 16 Model: M,M,N - Multiplicative Error, Multiplicative Trend, No Season (Auto E=*, T=*) Model selection: Akaike Information Criterion Convergence achieved on boundaries.
Parameters	Parameters	Parameters
		Alpha: 0.000000

Alpha:	0.000000
Beta:	0.000000
Gamma:	0.000000
Initial Parameters	
Initial level:	0.019844
Initial trend:	0.941577
Initial state 1:	0.000000
Compact Log-likelihood	63.46838
Log-likelihood	62.94607
Akaike Information Criterion	-116.9368
Schwarz Criterion	-113.0738
Hannan-Quinn Criterion	-116.7389
Sum of Squared Residuals	2.533457
Root Mean Squared Error	0.397921
Average Mean Squared Error	2.18E-05

Alpha:	0.000000
Beta:	0.000000
Gamma:	0.000000
Initial Parameters	
Initial level:	0.019844
Initial trend:	0.941577
Initial state 1:	1.000000
Compact Log-likelihood	63.46838
Log-likelihood	62.94607
Akaike Information Criterion	-116.9368
Schwarz Criterion	-113.0738
Hannan-Quinn Criterion	-116.7389
Sum of Squared Residuals	2.533457
Root Mean Squared Error	0.397921
Average Mean Squared Error	2.18E-05

Beta:	0.000000
Initial Parameters	
Initial level:	0.019844
Initial trend:	0.941577
Compact Log-likelihood	63.46838
Log-likelihood	62.94607
Akaike Information Criterion	-118.9368
Schwarz Criterion	-115.8464
Hannan-Quinn Criterion	-118.7785
Sum of Squared Residuals	2.533457
Root Mean Squared Error	0.397921
Average Mean Squared Error	2.18E-05

Coal No Days Lost, Automatic Trend and Error, Additive Seasonal

MODEL SUMMARY

ETS Smoothing
Original series: CNDL_IR
Sample: 2003 2018
Included observations: 16
Model: M,M,A - Multiplicative Error, Multiplicative
Trend, Additive Season (Auto E=*, T=*)
Model selection: Akaike Information Criterion
Convergence achieved on boundaries.

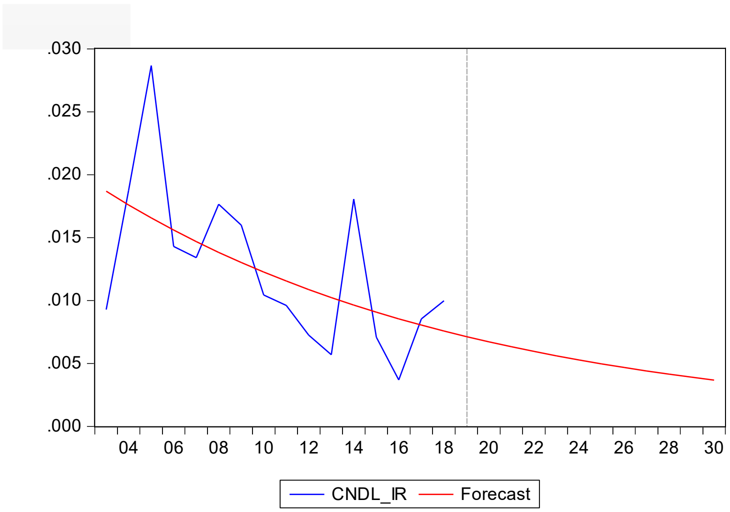
Parameters	
Alpha:	0.000000
Beta:	0.000000
Gamma:	0.000000

Initial Parameters	
Initial level:	0.019844
Initial trend:	0.941577
Initial state 1:	0.000000

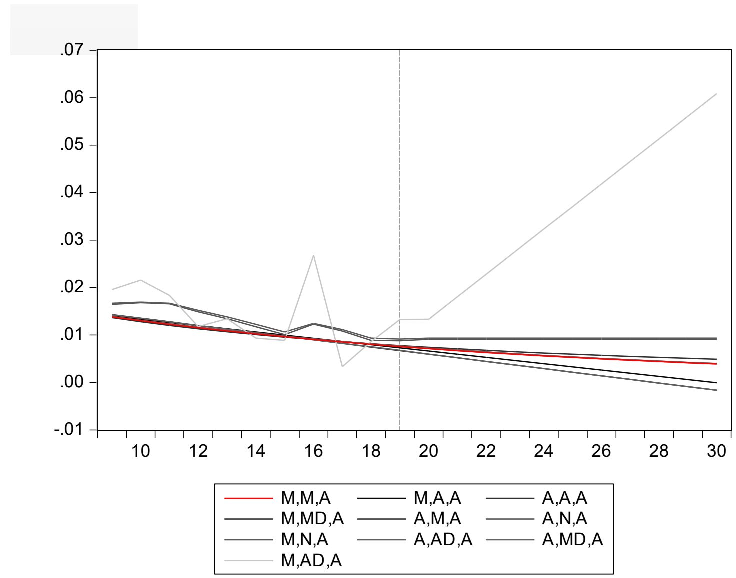
Compact Log-likelihood	63.46838
Log-likelihood	62.94607
Akaike Information Criterion	-116.9368
Schwarz Criterion	-113.0738
Hannan-Quinn Criterion	-116.7389
Sum of Squared Residuals	2.533457
Root Mean Squared Error	0.397921

Average Mean Squared Error	2.18E-05

Decomposition Graph



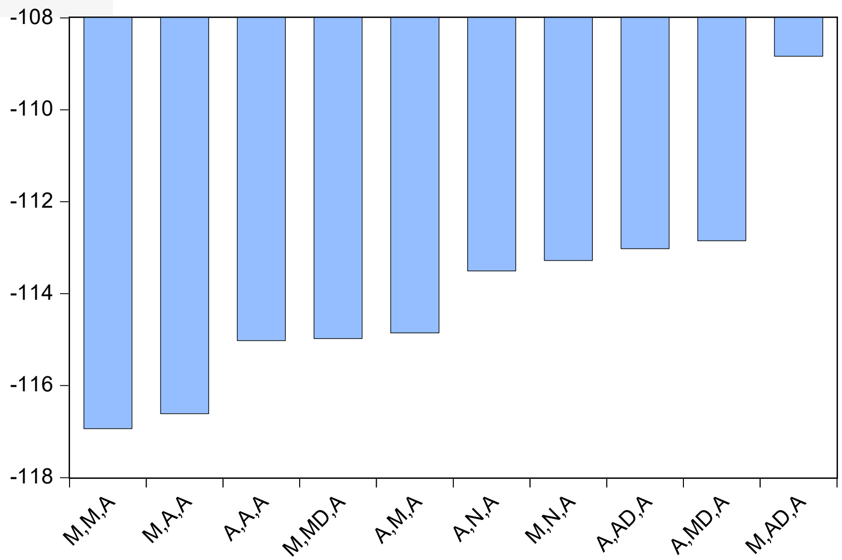
Forecast Comparison Graph



FORECAST COMPARISON TABLE

	Actuals	M,M,A	M,A,A	A,A,A	M,MD,A	A,M,A	A,N,A	M,N,A	A,AD,A	A,MD,A	M,AD,A
2003	0.0093	0.0187	0.0173	0.0181	0.0194	0.0187	0.0155	0.0165	0.0182	0.0187	0.0079
2004	0.0188	0.0176	0.0167	0.0173	0.0180	0.0176	0.0138	0.0147	0.0174	0.0176	0.0146
2005	0.0287	0.0166	0.0160	0.0166	0.0168	0.0166	0.0152	0.0157	0.0166	0.0166	0.0253
2006	0.0143	0.0156	0.0153	0.0158	0.0156	0.0156	0.0189	0.0189	0.0158	0.0156	0.0349
2007	0.0134	0.0147	0.0147	0.0151	0.0146	0.0147	0.0176	0.0178	0.0150	0.0147	0.0101
2008	0.0176	0.0138	0.0140	0.0143	0.0136	0.0139	0.0165	0.0167	0.0143	0.0139	0.0196
2009	0.0160	0.0130	0.0133	0.0135	0.0128	0.0131	0.0168	0.0169	0.0135	0.0131	0.0216
2010	0.0104	0.0123	0.0127	0.0128	0.0120	0.0123	0.0166	0.0167	0.0127	0.0123	0.0183
2011	0.0096	0.0115	0.0120	0.0120	0.0113	0.0116	0.0149	0.0152	0.0120	0.0116	0.0118
2012	0.0073	0.0109	0.0113	0.0113	0.0107	0.0109	0.0134	0.0138	0.0112	0.0109	0.0134
2013	0.0057	0.0102	0.0106	0.0105	0.0101	0.0103	0.0117	0.0122	0.0105	0.0103	0.0093
2014	0.0181	0.0096	0.0100	0.0097	0.0095	0.0097	0.0101	0.0106	0.0097	0.0097	0.0089
2015	0.0071	0.0091	0.0093	0.0090	0.0090	0.0092	0.0123	0.0124	0.0090	0.0092	0.0268
2016	0.0037	0.0085	0.0086	0.0082	0.0086	0.0086	0.0108	0.0111	0.0082	0.0086	0.0033
2017	0.0085	0.0080	0.0080	0.0075	0.0082	0.0081	0.0089	0.0093	0.0075	0.0081	0.0086
2018	0.0100	0.0076	0.0073	0.0067	0.0078	0.0077	0.0088	0.0091	0.0068	0.0077	0.0133
2019	NA	0.0071	0.0066	0.0059	0.0074	0.0072	0.0091	0.0093	0.0059	0.0072	0.0133
2020	NA	0.0067	0.0060	0.0052	0.0071	0.0068	0.0091	0.0093	0.0052	0.0068	0.0181
2021	NA	0.0063	0.0053	0.0044	0.0068	0.0064	0.0091	0.0093	0.0044	0.0064	0.0228
2022	NA	0.0060	0.0046	0.0037	0.0065	0.0060	0.0091	0.0093	0.0037	0.0060	0.0276
2023	NA	0.0056	0.0040	0.0029	0.0062	0.0057	0.0091	0.0093	0.0029	0.0057	0.0323
2024	NA	0.0053	0.0033	0.0021	0.0059	0.0054	0.0091	0.0093	0.0021	0.0054	0.0371
2025	NA	0.0050	0.0026	0.0014	0.0057	0.0051	0.0091	0.0093	0.0014	0.0051	0.0418
2026	NA	0.0047	0.0020	0.0006	0.0055	0.0048	0.0091	0.0093	0.0006	0.0048	0.0466
2027	NA	0.0044	0.0013	-0.0001	0.0053	0.0045	0.0091	0.0093	-0.0001	0.0045	0.0513
2028	NA	0.0041	0.0006	-0.0009	0.0051	0.0042	0.0091	0.0093	-0.0009	0.0042	0.0561

AIC COMPARISON GRAPH



LL-Based Comparison Table

Model	Compact LL	Likelihood	AIC*	BIC	HQ	AMSE
M,M,A	63.4684	62.9461	-116.937	-113.074	-116.739	2.2E-05
M,A,A	63.3047	62.7824	-116.609	-112.746	-116.412	2.3E-05
A,A,A	62.5101	61.9878	-115.020	-111.157	-114.822	2.2E-05
M,MD,A	63.4890	62.9667	-114.978	-110.343	-114.741	2.2E-05
A,M,	62.4256	61.9033	-114.851	-110.988	-114.653	2.2E-05

A						
A,N, A	59.7540	59.2317	-113.508	-111.190	-113.389	3.6E-05
M,N, A	59.6398	59.1175	-113.280	-110.962	-113.161	3.5E-05
A,AD ,A	62.5110	61.9887	-113.022	-108.387	-112.785	NA
A,M D,A	62.4256	61.9033	-112.851	-108.216	-112.614	2.2E-05
M,A D,A	60.4175	59.8952	-108.835	-104.200	-108.598	0.00016

Coal No Days Lost, Automatic Trend and Error, Multiplicative Seasonal

MODEL SUMMARY

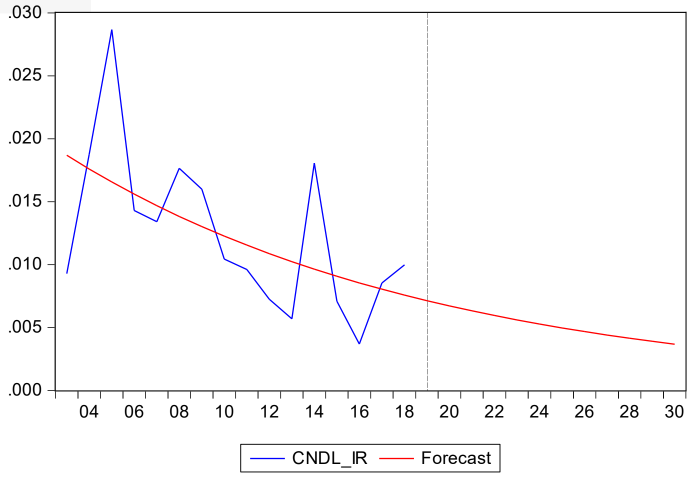
ETS Smoothing
Original series: CNDL_IR
Sample: 2003 2018
Included observations: 16
Model: M,M,M - Multiplicative Error, Multiplicative
Trend, Multiplicative Season (Auto E=*, T=*)
Model selection: Akaike Information Criterion
Convergence achieved on boundaries.

Parameters	
Alpha:	0.000000
Beta:	0.000000
Gamma:	0.000000

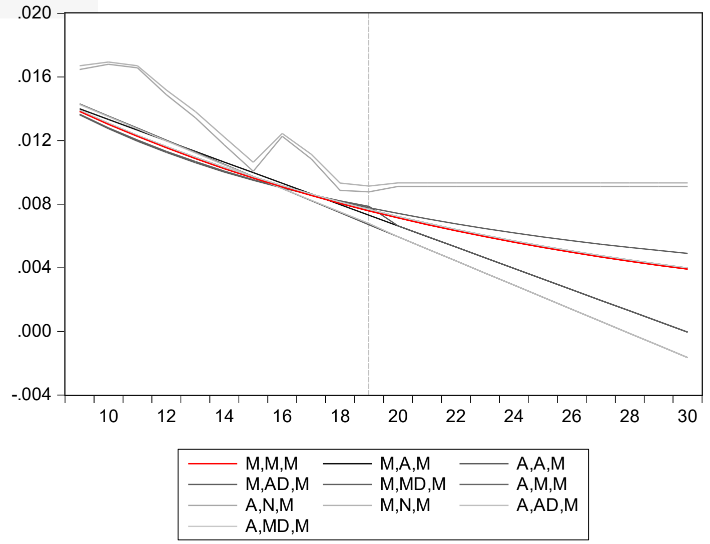
Initial Parameters	
Initial level:	0.019844
Initial trend:	0.941577
Initial state 1:	1.000000

Compact Log-likelihood	63.46838
Log-likelihood	62.94607
Akaike Information Criterion	-116.9368
Schwarz Criterion	-113.0738
Hannan-Quinn Criterion	-116.7389
Sum of Squared Residuals	2.533457
Root Mean Squared Error	0.397921
Average Mean Squared Error	2.18E-05

Decomposition Graph



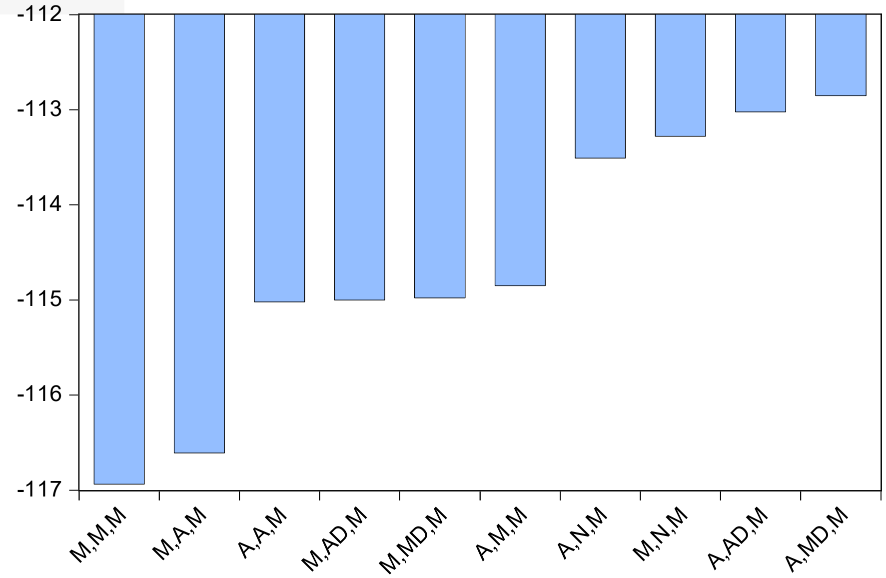
Forecast Comparison Graph



FORECAST COMPARISON TABLE

	Actuals	M,M,M	M,A,M	A,A,M	M,AD,M	M,MD,M	A,M,M	A,N,M	M,N,M	A,AD,M	A,MD,M
2003	0.0093	0.0187	0.0173	0.0181	0.0196	0.0194	0.0187	0.0155	0.0165	0.0182	0.0187
2004	0.0188	0.0176	0.0167	0.0173	0.0181	0.0180	0.0176	0.0138	0.0147	0.0174	0.0176
2005	0.0287	0.0166	0.0160	0.0166	0.0168	0.0168	0.0166	0.0152	0.0157	0.0166	0.0166
2006	0.0143	0.0156	0.0153	0.0158	0.0157	0.0156	0.0156	0.0189	0.0189	0.0158	0.0156
2007	0.0134	0.0147	0.0147	0.0151	0.0146	0.0146	0.0147	0.0176	0.0178	0.0150	0.0147
2008	0.0176	0.0138	0.0140	0.0143	0.0136	0.0136	0.0139	0.0165	0.0167	0.0143	0.0139
2009	0.0160	0.0130	0.0133	0.0135	0.0127	0.0128	0.0131	0.0168	0.0169	0.0135	0.0131
2010	0.0104	0.0123	0.0127	0.0128	0.0120	0.0120	0.0123	0.0166	0.0167	0.0127	0.0123
2011	0.0096	0.0115	0.0120	0.0120	0.0112	0.0113	0.0116	0.0149	0.0152	0.0120	0.0116
2012	0.0073	0.0109	0.0113	0.0113	0.0106	0.0107	0.0109	0.0134	0.0138	0.0112	0.0109
2013	0.0057	0.0102	0.0106	0.0105	0.0100	0.0101	0.0103	0.0117	0.0122	0.0105	0.0103
2014	0.0181	0.0096	0.0100	0.0097	0.0095	0.0095	0.0097	0.0101	0.0106	0.0097	0.0097
2015	0.0071	0.0091	0.0093	0.0090	0.0090	0.0090	0.0092	0.0123	0.0124	0.0090	0.0092
2016	0.0037	0.0085	0.0086	0.0082	0.0086	0.0086	0.0086	0.0108	0.0111	0.0082	0.0086
2017	0.0085	0.0080	0.0080	0.0075	0.0082	0.0082	0.0081	0.0089	0.0093	0.0075	0.0081
2018	0.0100	0.0076	0.0073	0.0067	0.0079	0.0078	0.0077	0.0088	0.0091	0.0068	0.0077
2019	NA	0.0071	0.0066	0.0059	0.0066	0.0074	0.0072	0.0091	0.0093	0.0059	0.0072
2020	NA	0.0067	0.0060	0.0052	0.0060	0.0071	0.0068	0.0091	0.0093	0.0052	0.0068
2021	NA	0.0063	0.0053	0.0044	0.0053	0.0068	0.0064	0.0091	0.0093	0.0044	0.0064
2022	NA	0.0060	0.0046	0.0037	0.0046	0.0065	0.0060	0.0091	0.0093	0.0037	0.0060
2023	NA	0.0056	0.0040	0.0029	0.0040	0.0062	0.0057	0.0091	0.0093	0.0029	0.0057
2024	NA	0.0053	0.0033	0.0021	0.0033	0.0059	0.0054	0.0091	0.0093	0.0021	0.0054
2025	NA	0.0050	0.0026	0.0014	0.0026	0.0057	0.0051	0.0091	0.0093	0.0014	0.0051
2026	NA	0.0047	0.0020	0.0006	0.0020	0.0055	0.0048	0.0091	0.0093	0.0006	0.0048
2027	NA	0.0044	0.0013	-0.0001	0.0013	0.0053	0.0045	0.0091	0.0093	-0.0001	0.0045
2028	NA	0.0041	0.0006	-0.0009	0.0006	0.0051	0.0042	0.0091	0.0093	-0.0009	0.0042

AIC COMPARISON GRAPH



LL-Based Comparison Table

Model	Compact LL	Likelihood	AIC*	BIC	HQ	AMSE
M,M,M	63.4684	62.9461	-116.937	-113.074	-116.739	2.2E-05
M,A,M	63.3047	62.7824	-116.609	-112.746	-116.412	2.3E-05
A,A,M	62.5101	61.9878	-115.020	-111.157	-114.822	2.2E-05
M,AD, M	63.5000	62.9777	-115.000	-110.364	-114.763	NA
M,MD, M	63.4890	62.9667	-114.978	-110.343	-114.741	2.2E-05
A,M,M	62.4256	61.9033	-114.851	-110.988	-114.653	2.2E-05

A,N,M	59.7540	59.2317	-113.508	-111.190	-113.389	3.6E-05
M,N,M	59.6398	59.1175	-113.280	-110.962	-113.161	3.5E-05
A,AD,M	62.5110	61.9887	-113.022	-108.387	-112.785	NA
A,MD,M	62.4256	61.9033	-112.851	-108.216	-112.614	2.2E-05

Coal No Days Lost, Automatic Trend and Error, No Seasonal

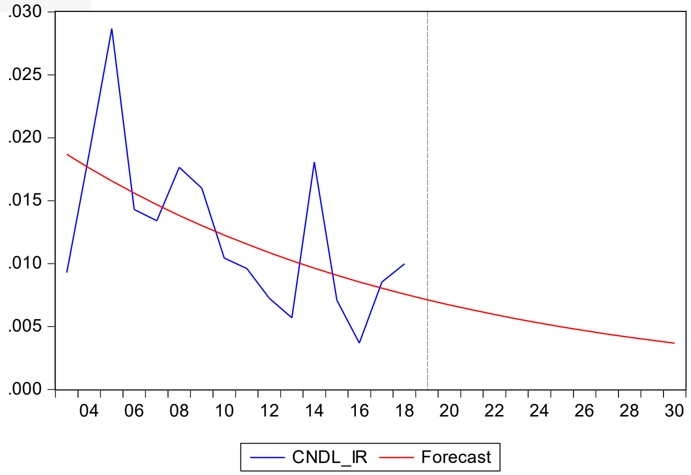
MODEL SUMMARY

ETS Smoothing
Original series: CNDL_IR
Sample: 2003 2018
Included observations: 16
Model: M,M,N - Multiplicative Error, Multiplicative
Trend, No Season (Auto E=*, T=*)
Model selection: Akaike Information Criterion
Convergence achieved on boundaries.

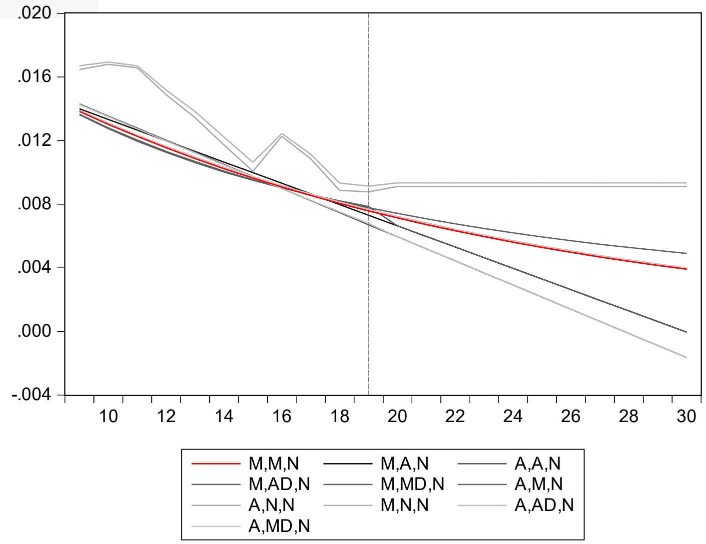
Parameters	
Alpha:	0.000000
Beta:	0.000000
Initial Parameters	
Initial level:	0.019844
Initial trend:	0.941577
Compact Log-likelihood	63.46838
Log-likelihood	62.94607
Akaike Information Criterion	-118.9368
Schwarz Criterion	-115.8464
Hannan-Quinn Criterion	-118.7785

Sum of Squared Residuals	2.533457
Root Mean Squared Error	0.397921
Average Mean Squared Error	2.18E-05

Decomposition Graph



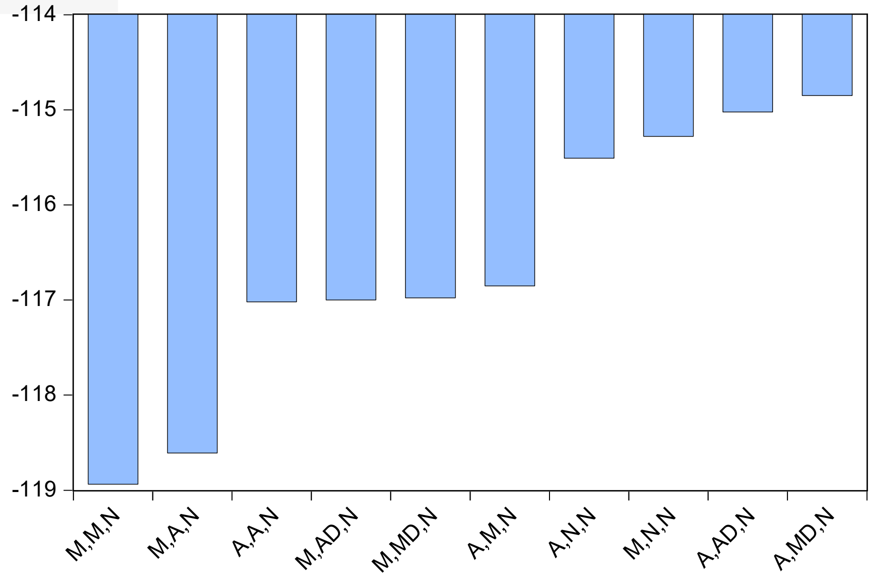
Forecast Comparison Graph



FORECAST COMPARISON TABLE

	Actuals	M,M,N	M,A,N	A,A,N	M,AD,N	M,MD,N	A,M,N	A,N,N	M,N,N	A,AD,N	A,MD,N
2003	0.0093	0.0187	0.0173	0.0181	0.0196	0.0194	0.0187	0.0155	0.0165	0.0182	0.0187
2004	0.0188	0.0176	0.0167	0.0173	0.0181	0.0180	0.0176	0.0138	0.0147	0.0174	0.0176
2005	0.0287	0.0166	0.0160	0.0166	0.0168	0.0168	0.0166	0.0152	0.0157	0.0166	0.0166
2006	0.0143	0.0156	0.0153	0.0158	0.0157	0.0156	0.0156	0.0189	0.0189	0.0158	0.0156
2007	0.0134	0.0147	0.0147	0.0151	0.0146	0.0146	0.0147	0.0176	0.0178	0.0150	0.0147
2008	0.0176	0.0138	0.0140	0.0143	0.0136	0.0136	0.0139	0.0165	0.0167	0.0143	0.0139
2009	0.0160	0.0130	0.0133	0.0135	0.0127	0.0128	0.0131	0.0168	0.0169	0.0135	0.0131
2010	0.0104	0.0123	0.0127	0.0128	0.0120	0.0120	0.0123	0.0166	0.0167	0.0127	0.0123
2011	0.0096	0.0115	0.0120	0.0120	0.0112	0.0113	0.0116	0.0149	0.0152	0.0120	0.0116
2012	0.0073	0.0109	0.0113	0.0113	0.0106	0.0107	0.0109	0.0134	0.0138	0.0112	0.0109
2013	0.0057	0.0102	0.0106	0.0105	0.0100	0.0101	0.0103	0.0117	0.0122	0.0105	0.0103
2014	0.0181	0.0096	0.0100	0.0097	0.0095	0.0095	0.0097	0.0101	0.0106	0.0097	0.0097
2015	0.0071	0.0091	0.0093	0.0090	0.0090	0.0090	0.0092	0.0123	0.0124	0.0090	0.0092
2016	0.0037	0.0085	0.0086	0.0082	0.0086	0.0086	0.0086	0.0108	0.0111	0.0082	0.0086
2017	0.0085	0.0080	0.0080	0.0075	0.0082	0.0082	0.0081	0.0089	0.0093	0.0075	0.0081
2018	0.0100	0.0076	0.0073	0.0067	0.0079	0.0078	0.0077	0.0088	0.0091	0.0068	0.0077
2019	NA	0.0071	0.0066	0.0059	0.0066	0.0074	0.0072	0.0091	0.0093	0.0059	0.0072
2020	NA	0.0067	0.0060	0.0052	0.0060	0.0071	0.0068	0.0091	0.0093	0.0052	0.0068
2021	NA	0.0063	0.0053	0.0044	0.0053	0.0068	0.0064	0.0091	0.0093	0.0044	0.0064
2022	NA	0.0060	0.0046	0.0037	0.0046	0.0065	0.0060	0.0091	0.0093	0.0037	0.0060
2023	NA	0.0056	0.0040	0.0029	0.0040	0.0062	0.0057	0.0091	0.0093	0.0029	0.0057
2024	NA	0.0053	0.0033	0.0021	0.0033	0.0059	0.0054	0.0091	0.0093	0.0021	0.0054
2025	NA	0.0050	0.0026	0.0014	0.0026	0.0057	0.0051	0.0091	0.0093	0.0014	0.0051
2026	NA	0.0047	0.0020	0.0006	0.0020	0.0055	0.0048	0.0091	0.0093	0.0006	0.0048
2027	NA	0.0044	0.0013	-0.0001	0.0013	0.0053	0.0045	0.0091	0.0093	-0.0001	0.0045
2028	NA	0.0041	0.0006	-0.0009	0.0006	0.0051	0.0042	0.0091	0.0093	-0.0009	0.0042

AIC COMPARISON GRAPH



LL-Based Comparison Table

Model	Compact LL	Likelihood	AIC*	BIC	HQ	AMSE
M,M,N	63.4684	62.9461	-118.937	-115.846	-118.779	2.2E-05
M,A,N	63.3047	62.7824	-118.609	-115.519	-118.451	2.3E-05
A,A,N	62.5101	61.9878	-117.020	-113.930	-116.862	2.2E-05
M,AD,N	63.5000	62.9777	-117.000	-113.137	-116.802	NA
M,M	63.4890	62.9667	-116.978	-113.115	-116.780	2.2E-05

D,N						
A,M,N	62.4256	61.9033	-116.851	-113.761	-116.693	2.2E-05
A,N,N	59.7540	59.2317	-115.508	-113.963	-115.429	3.6E-05
M,N,N	59.6398	59.1175	-115.280	-113.734	-115.200	3.5E-05
A,AD,N	62.5110	61.9887	-115.022	-111.159	-114.824	NA
A,MD,N	62.4256	61.9033	-114.851	-110.988	-114.653	2.2E-05

APPENDIX D: INCIDENT RATE MODELING, METAL NONMETAL

Summary of Model Selection Outputs, Metal Nonmetal Fatality Incident Rate

The fully automatic method of ETS fails automatic selection of seasonality as the time series is too short. Manually executing the ETS procedure with the seasonality set to additive, multiplicative, and none results in the all three specifications converging at the boundaries. The AIC difference is attributable to the difference in the number of parameters. Since the two models produce essentially the same model outputs, the simpler A,M,N was the best ETS fit. However, Appendix G explains the forecast override to the Metal Nonmetal mines fatality incident rate forecast.

ETS Smoothing
Original series: MF_IR
Sample: 2003 2018
Included observations: 16
Model: A,M,A - Additive Error, Multiplicative Trend,
Additive Season (Auto E=*, T=*)
Model selection: Akaike Information Criterion
Convergence achieved on boundaries.

Parameters	
Alpha:	0.000000
Beta:	0.000000
Gamma:	0.000000

Initial Parameters	
Initial level:	0.001662
Initial trend:	1.054622
Initial state 1:	0.000000

Compact Log-likelihood	89.07203
Log-likelihood	88.54973

ETS Smoothing
Original series: MF_IR
Sample: 2003 2018
Included observations: 16
Model: M,MD,M - Multiplicative Error, Multiplicative
-Dampened Trend, Multiplicative Season
(Auto E=*, T=*)
Model selection: Akaike Information Criterion
Convergence achieved on boundaries.

Parameters	
Alpha:	0.000000
Beta:	NA
Gamma:	0.000000
Phi:	0.328961

Initial Parameters	
Initial level:	2.41E-05
Initial trend:	18417.69

ETS Smoothing
Original series: MF_IR
Sample: 2003 2018
Included observations: 16
Model: A,M,N - Additive Error, Multiplicative Trend,
No Season (Auto E=*, T=*)
Model selection: Akaike Information Criterion
Convergence achieved on boundaries.

Parameters	
Alpha:	0.000000
Beta:	0.000000

Initial Parameters	
Initial level:	0.001662
Initial trend:	1.054622

Compact Log-likelihood	89.07203
Log-likelihood	88.54973
Akaike Information Criterion	-170.1441
Schwarz Criterion	-167.0537

Akaike Information Criterion	-168.1441
Schwarz Criterion	-164.2811
Hannan-Quinn Criterion	-167.9462
Sum of Squared Residuals	1.46E-05
Root Mean Squared Error	0.000955
Average Mean Squared Error	8.60E-07

Initial state 1:	1.000000
Compact Log-likelihood	90.09072
Log-likelihood	89.56842
Akaike Information Criterion	-168.1814
Schwarz Criterion	-163.5459
Hannan-Quinn Criterion	-167.9441
Sum of Squared Residuals	1.922116
Root Mean Squared Error	0.346601
Average Mean Squared Error	8.98E-06

Hannan-Quinn Criterion	-169.9858
Sum of Squared Residuals	1.46E-05
Root Mean Squared Error	0.000955
Average Mean Squared Error	8.60E-07

Metal Nonmetal Fatality Incident Rate, Automatic Trend and Error, Additive Seasonal

MODEL SUMMARY

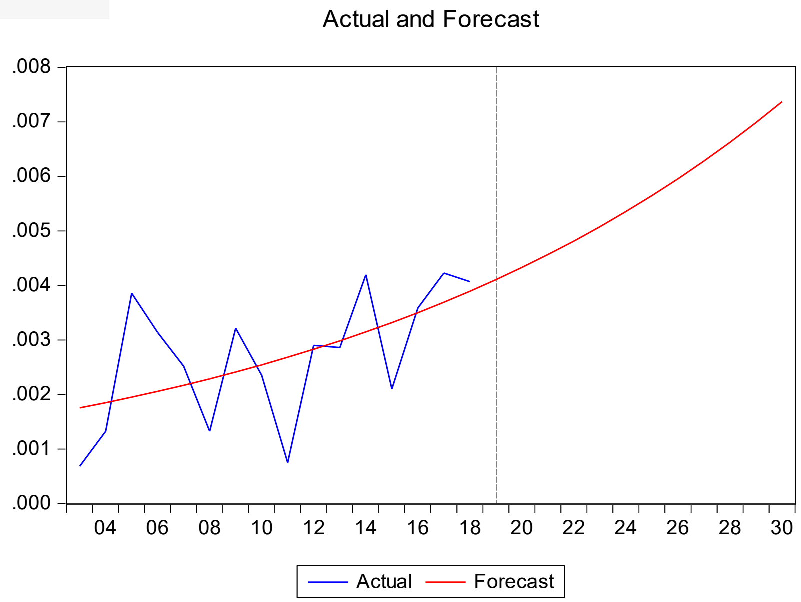
ETS Smoothing
Original series: MF_IR
Sample: 2003 2018
Included observations: 16
Model: A,M,A - Additive Error, Multiplicative Trend,
Additive Season (Auto E=*, T=*)
Model selection: Akaike Information Criterion
Convergence achieved on boundaries.

Parameters	
Alpha:	0.000000
Beta:	0.000000
Gamma:	0.000000

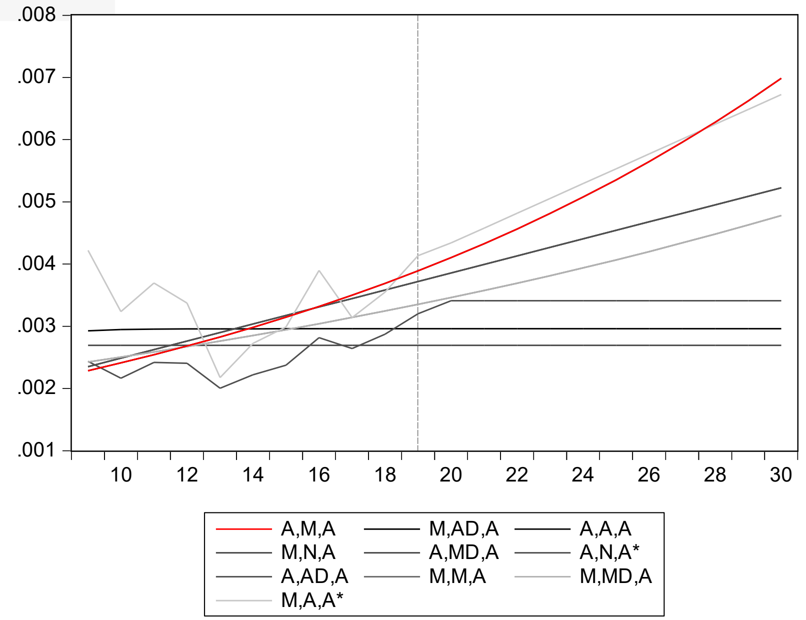
Initial Parameters

Initial level:	0.001662
Initial trend:	1.054622
Initial state 1:	0.000000
Compact Log-likelihood	89.07203
Log-likelihood	88.54973
Akaike Information Criterion	-168.1441
Schwarz Criterion	-164.2811
Hannan-Quinn Criterion	-167.9462
Sum of Squared Residuals	1.46E-05
Root Mean Squared Error	0.000955
Average Mean Squared Error	8.60E-07

Decomposition Graph



Forecast Comparison Graph

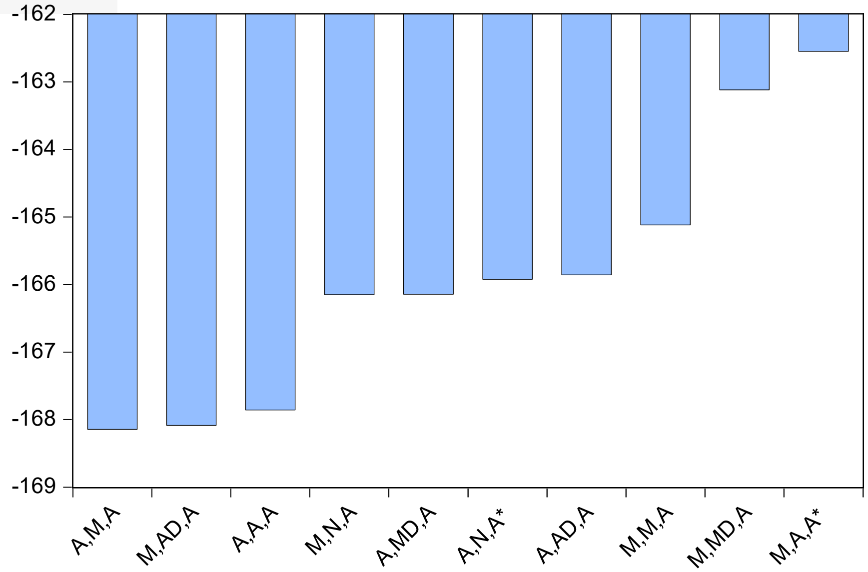


FORECAST COMPARISON TABLE

	Actuals	A,M,A	M,AD,A	A,A,A	M,N,A	A,MD,A	A,N,A*	A,AD,A	M,M,A	M,MD,A	M,A,A*
2003	0.0007	0.0018	0.0006	0.0017	0.0027	0.0018	0.0021	0.0017	0.0021	0.0021	0.0006
2004	0.0013	0.0018	0.0020	0.0018	0.0027	0.0018	0.0017	0.0018	0.0021	0.0021	0.0015
2005	0.0039	0.0019	0.0025	0.0019	0.0027	0.0019	0.0016	0.0019	0.0022	0.0022	0.0022
2006	0.0031	0.0021	0.0028	0.0021	0.0027	0.0021	0.0022	0.0021	0.0023	0.0023	0.0040
2007	0.0025	0.0022	0.0029	0.0022	0.0027	0.0022	0.0024	0.0022	0.0023	0.0023	0.0045
2008	0.0013	0.0023	0.0029	0.0024	0.0027	0.0023	0.0024	0.0024	0.0024	0.0024	0.0042
2009	0.0032	0.0024	0.0029	0.0025	0.0027	0.0024	0.0022	0.0025	0.0025	0.0025	0.0032
2010	0.0024	0.0025	0.0030	0.0026	0.0027	0.0025	0.0024	0.0026	0.0026	0.0026	0.0037
2011	0.0007	0.0027	0.0030	0.0028	0.0027	0.0027	0.0024	0.0028	0.0027	0.0027	0.0034
2012	0.0029	0.0028	0.0030	0.0029	0.0027	0.0028	0.0020	0.0029	0.0028	0.0028	0.0022
2013	0.0029	0.0030	0.0030	0.0030	0.0027	0.0030	0.0022	0.0030	0.0029	0.0029	0.0027
2014	0.0042	0.0031	0.0030	0.0032	0.0027	0.0031	0.0024	0.0032	0.0029	0.0029	0.0030
2015	0.0021	0.0033	0.0030	0.0033	0.0027	0.0033	0.0028	0.0033	0.0030	0.0030	0.0039
2016	0.0036	0.0035	0.0030	0.0034	0.0027	0.0035	0.0026	0.0034	0.0031	0.0031	0.0031
2017	0.0042	0.0037	0.0030	0.0036	0.0027	0.0037	0.0029	0.0036	0.0032	0.0032	0.0035
2018	0.0041	0.0039	0.0030	0.0037	0.0027	0.0039	0.0032	0.0037	0.0034	0.0034	0.0041
2019	NA	0.0041	0.0030	0.0039	0.0027	0.0041	0.0034	0.0039	0.0035	0.0035	0.0043
2020	NA	0.0043	0.0030	0.0040	0.0027	0.0043	0.0034	0.0040	0.0036	0.0036	0.0046
2021	NA	0.0046	0.0030	0.0041	0.0027	0.0046	0.0034	0.0041	0.0037	0.0037	0.0048
2022	NA	0.0048	0.0030	0.0043	0.0027	0.0048	0.0034	0.0043	0.0038	0.0038	0.0051
2023	NA	0.0051	0.0030	0.0044	0.0027	0.0051	0.0034	0.0044	0.0039	0.0039	0.0053
2024	NA	0.0054	0.0030	0.0045	0.0027	0.0054	0.0034	0.0045	0.0041	0.0041	0.0055
2025	NA	0.0056	0.0030	0.0047	0.0027	0.0056	0.0034	0.0047	0.0042	0.0042	0.0058
2026	NA	0.0060	0.0030	0.0048	0.0027	0.0060	0.0034	0.0048	0.0043	0.0043	0.0060
2027	NA	0.0063	0.0030	0.0050	0.0027	0.0063	0.0034	0.0050	0.0045	0.0045	0.0062
2028	NA	0.0066	0.0030	0.0051	0.0027	0.0066	0.0034	0.0051	0.0046	0.0046	0.0065

*2 models failed to converge

AIC COMPARISON GRAPH



LL-Based Comparison Table

Model	Compact LL	Likelihood	AIC*	BIC	HQ	AMSE
A,M,A	89.0720	88.5497	-168.144	-164.281	-167.946	8.6E-07
M,AD,A	90.0432	89.5208	-168.086	-163.451	-167.849	1.1E-06
A,A,A	88.9285	88.4062	-167.857	-163.994	-167.659	8.8E-07
M,N,A	86.0758	85.5535	-166.152	-163.834	-166.033	1.1E-06

A,MD,A	89.0720	88.5497	-166.144	-161.509	-165.907	8.6E-07
A,N,A*	85.9615	85.4392	-165.923	-163.605	-165.804	1.3E-06
A,AD,A	88.9285	88.4062	-165.857	-161.221	-165.620	8.8E-07
M,M,A	87.5596	87.0373	-165.119	-161.256	-164.921	8.9E-07
M,MD,A	87.5596	87.0373	-163.119	-158.484	-162.882	8.9E-07
M,A,A*	86.2744	85.7520	-162.549	-158.686	-162.351	3.0E-06

*2 models failed to converge

Metal Nonmetal Fatality Incident Rate, Automatic Trend and Error, Multiplicative Seasonal

MODEL SUMMARY

ETS Smoothing
Original series: MF_IR
Sample: 2003 2018
Included observations: 16
Model: M,MD,M - Multiplicative Error, Multiplicative
-Dampened Trend, Multiplicative Season
(Auto E=*, T=*)
Model selection: Akaike Information Criterion
Convergence achieved on boundaries.

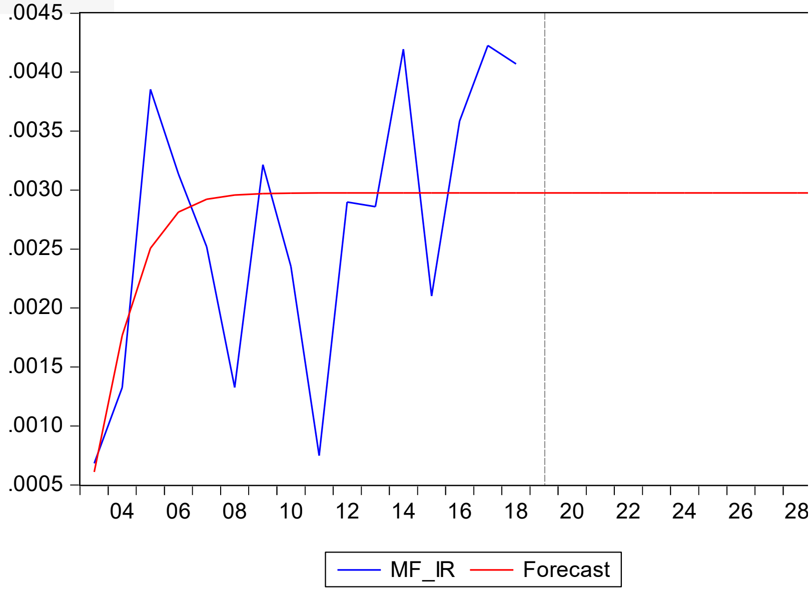
Parameters	
Alpha:	0.000000
Beta:	NA
Gamma:	0.000000
Phi:	0.328961

Initial Parameters	
Initial level:	2.41E-05
Initial trend:	18417.69
Initial state 1:	1.000000

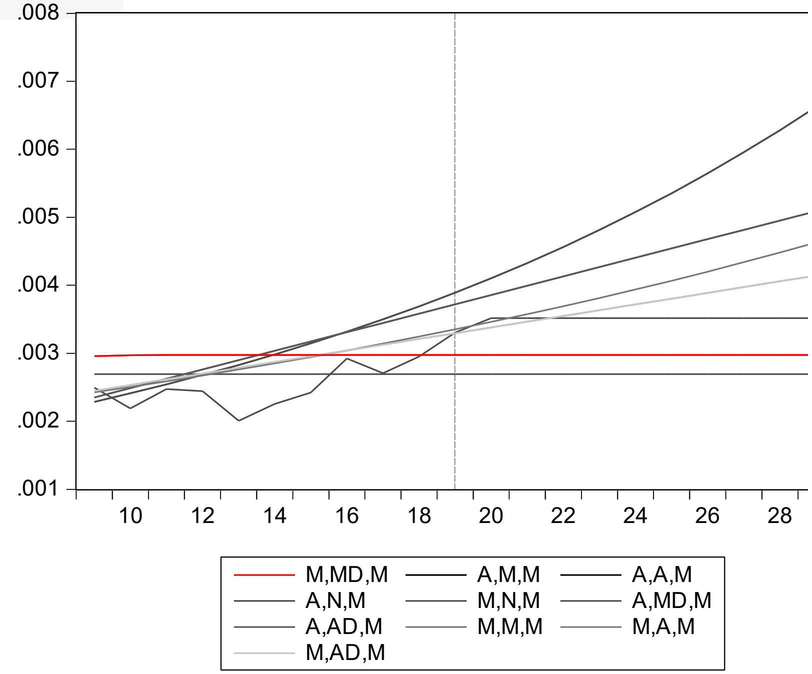
Compact Log-likelihood	90.09072
Log-likelihood	89.56842
Akaike Information Criterion	-168.1814
Schwarz Criterion	-163.5459
Hannan-Quinn Criterion	-167.9441

Sum of Squared Residuals	1.922116
Root Mean Squared Error	0.346601
Average Mean Squared Error	8.98E-06

Decomposition Graph



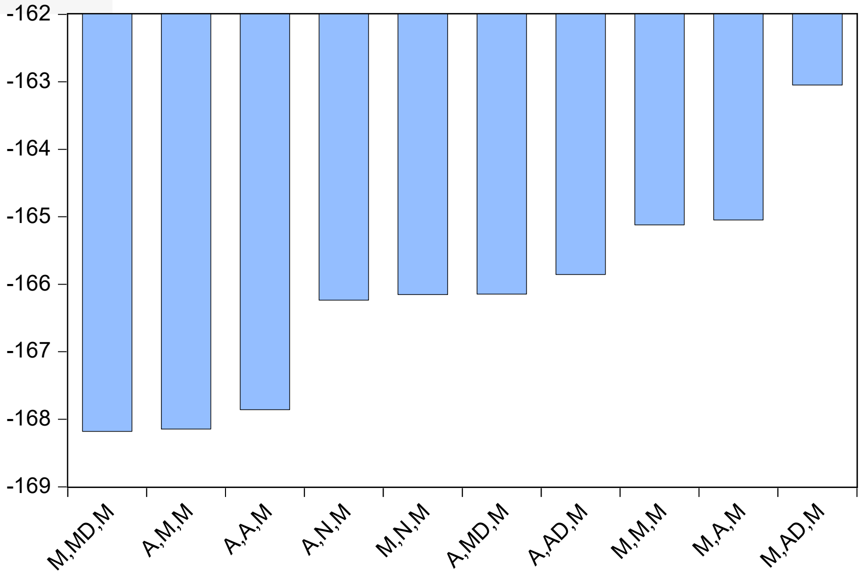
Forecast Comparison Graph



FORECAST COMPARISON TABLE

	Actuals	M,MD,M	A,M,M	A,A,M	A,N,M	M,N,M	A,MD,M	A,AD,M	M,M,M	M,A,M	M,AD,M
2003	0.0007	0.0006	0.0018	0.0017	0.0020	0.0027	0.0018	0.0017	0.0021	0.0020	0.0020
2004	0.0013	0.0018	0.0018	0.0018	0.0016	0.0027	0.0018	0.0018	0.0021	0.0021	0.0021
2005	0.0039	0.0025	0.0019	0.0019	0.0016	0.0027	0.0019	0.0019	0.0022	0.0022	0.0022
2006	0.0031	0.0028	0.0021	0.0021	0.0022	0.0027	0.0021	0.0021	0.0023	0.0023	0.0023
2007	0.0025	0.0029	0.0022	0.0022	0.0025	0.0027	0.0022	0.0022	0.0023	0.0024	0.0024
2008	0.0013	0.0030	0.0023	0.0024	0.0025	0.0027	0.0023	0.0024	0.0024	0.0024	0.0024
2009	0.0032	0.0030	0.0024	0.0025	0.0022	0.0027	0.0024	0.0025	0.0025	0.0025	0.0025
2010	0.0024	0.0030	0.0025	0.0026	0.0025	0.0027	0.0025	0.0026	0.0026	0.0026	0.0026
2011	0.0007	0.0030	0.0027	0.0028	0.0024	0.0027	0.0027	0.0028	0.0027	0.0027	0.0027
2012	0.0029	0.0030	0.0028	0.0029	0.0020	0.0027	0.0028	0.0029	0.0028	0.0028	0.0028
2013	0.0029	0.0030	0.0030	0.0030	0.0023	0.0027	0.0030	0.0030	0.0029	0.0029	0.0029
2014	0.0042	0.0030	0.0031	0.0032	0.0024	0.0027	0.0031	0.0032	0.0029	0.0030	0.0030
2015	0.0021	0.0030	0.0033	0.0033	0.0029	0.0027	0.0033	0.0033	0.0030	0.0030	0.0030
2016	0.0036	0.0030	0.0035	0.0034	0.0027	0.0027	0.0035	0.0034	0.0031	0.0031	0.0031
2017	0.0042	0.0030	0.0037	0.0036	0.0029	0.0027	0.0037	0.0036	0.0032	0.0032	0.0032
2018	0.0041	0.0030	0.0039	0.0037	0.0033	0.0027	0.0039	0.0037	0.0034	0.0033	0.0033
2019	NA	0.0030	0.0041	0.0039	0.0035	0.0027	0.0041	0.0039	0.0035	0.0034	0.0034
2020	NA	0.0030	0.0043	0.0040	0.0035	0.0027	0.0043	0.0040	0.0036	0.0035	0.0035
2021	NA	0.0030	0.0046	0.0041	0.0035	0.0027	0.0046	0.0041	0.0037	0.0035	0.0035
2022	NA	0.0030	0.0048	0.0043	0.0035	0.0027	0.0048	0.0043	0.0038	0.0036	0.0036
2023	NA	0.0030	0.0051	0.0044	0.0035	0.0027	0.0051	0.0044	0.0039	0.0037	0.0037
2024	NA	0.0030	0.0054	0.0045	0.0035	0.0027	0.0054	0.0045	0.0041	0.0038	0.0038
2025	NA	0.0030	0.0056	0.0047	0.0035	0.0027	0.0056	0.0047	0.0042	0.0039	0.0039
2026	NA	0.0030	0.0060	0.0048	0.0035	0.0027	0.0060	0.0048	0.0043	0.0040	0.0040
2027	NA	0.0030	0.0063	0.0050	0.0035	0.0027	0.0063	0.0050	0.0045	0.0041	0.0041
2028	NA	0.0030	0.0066	0.0051	0.0035	0.0027	0.0066	0.0051	0.0046	0.0041	0.0041

AIC COMPARISON GRAPH



LL-Based Comparison Table

Model	Compact LL	Likelihood	AIC*	BIC	HQ	AMSE
M,MD,M	90.0907	89.5684	-168.181	-163.546	-167.944	9.0E-06
A,M,M	89.0720	88.5497	-168.144	-164.281	-167.946	8.6E-07
A,A,M	88.9285	88.4062	-167.857	-163.994	-167.659	8.8E-07
A,N,M	86.1172	85.5949	-166.234	-163.917	-166.116	1.3E-06
M,N,M	86.0758	85.5535	-166.152	-163.834	-166.033	1.1E-06
A,MD,M	89.0720	88.5497	-166.144	-161.509	-165.907	8.6E-07

M	A,AD,M	88.9285	88.4062	-165.857	-161.221	-165.620	8.8E-07
M	M,M,M	87.5596	87.0373	-165.119	-161.256	-164.921	8.9E-07
	M,A,M	87.5234	87.0011	-165.047	-161.184	-164.849	9.0E-07
M	M,AD,M	87.5234	87.0011	-163.047	-158.411	-162.809	9.0E-07

Metal Nonmetal Fatality Incident Rate, Automatic Trend and Error, No Seasonal

MODEL SUMMARY

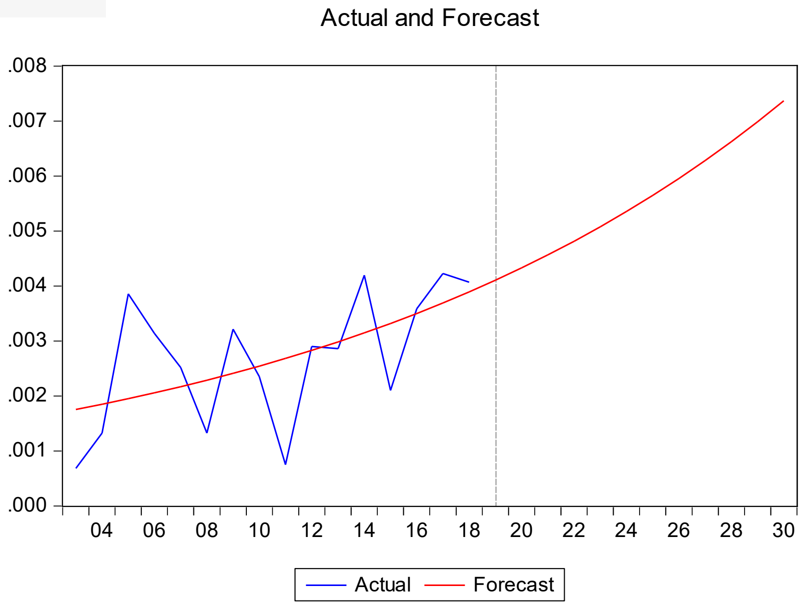
ETS Smoothing
Original series: MF_IR
Sample: 2003 2018
Included observations: 16
Model: A,M,N - Additive Error,
Multiplicative Trend,
No Season (Auto E=*, T=*)
Model selection: Akaike Information
Criterion
Convergence achieved on boundaries.

Parameters	
Alpha:	0.000000
Beta:	0.000000

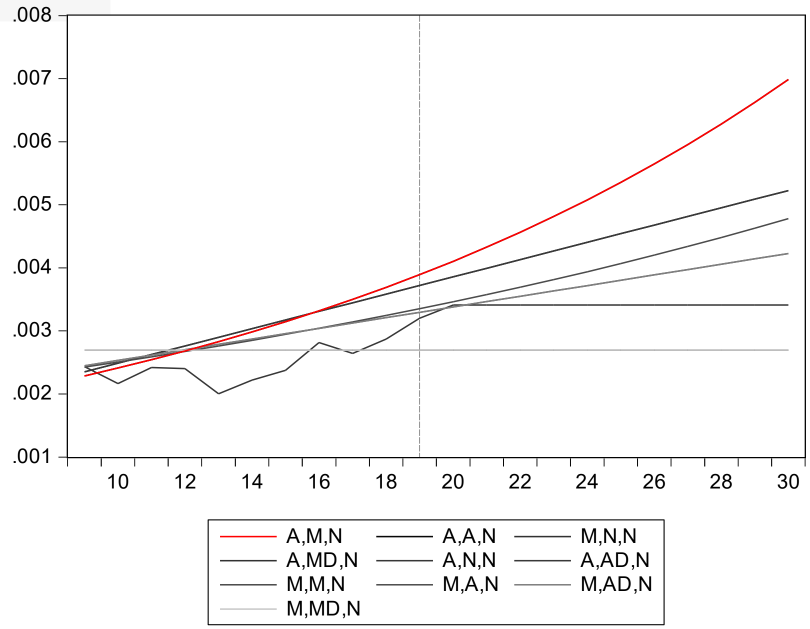
Initial Parameters	
Initial level:	0.001662
Initial trend:	1.054622

Compact Log-likelihood	89.07203
Log-likelihood	88.54973
Akaike Information Criterion	-170.1441
Schwarz Criterion	-167.0537
Hannan-Quinn Criterion	-169.9858
Sum of Squared Residuals	1.46E-05
Root Mean Squared Error	0.000955
Average Mean Squared Error	8.60E-07

Decomposition Graph



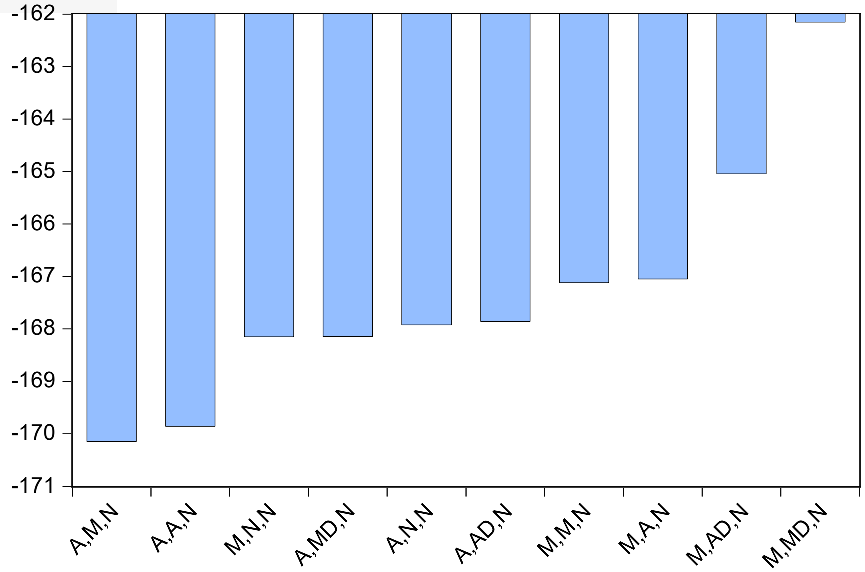
Forecast Comparison Graph



FORECAST COMPARISON TABLE

	Actuals	A,M,N	A,A,N	M,N,N	A,MD,N	A,N,N	A,AD,N	M,M,N	M,A,N	M,AD,N	M,MD,N
2003	0.0007	0.0018	0.0017	0.0027	0.0018	0.0021	0.0017	0.0021	0.0020	0.0020	0.0027
2004	0.0013	0.0018	0.0018	0.0027	0.0018	0.0017	0.0018	0.0021	0.0021	0.0021	0.0027
2005	0.0039	0.0019	0.0019	0.0027	0.0019	0.0016	0.0019	0.0022	0.0022	0.0022	0.0027
2006	0.0031	0.0021	0.0021	0.0027	0.0021	0.0022	0.0021	0.0023	0.0023	0.0023	0.0027
2007	0.0025	0.0022	0.0022	0.0027	0.0022	0.0024	0.0022	0.0023	0.0024	0.0024	0.0027
2008	0.0013	0.0023	0.0024	0.0027	0.0023	0.0024	0.0024	0.0024	0.0024	0.0024	0.0027
2009	0.0032	0.0024	0.0025	0.0027	0.0024	0.0022	0.0025	0.0025	0.0025	0.0025	0.0027
2010	0.0024	0.0025	0.0026	0.0027	0.0025	0.0024	0.0026	0.0026	0.0026	0.0026	0.0027
2011	0.0007	0.0027	0.0028	0.0027	0.0027	0.0024	0.0028	0.0027	0.0027	0.0027	0.0027
2012	0.0029	0.0028	0.0029	0.0027	0.0028	0.0020	0.0029	0.0028	0.0028	0.0028	0.0027
2013	0.0029	0.0030	0.0030	0.0027	0.0030	0.0022	0.0030	0.0029	0.0029	0.0029	0.0027
2014	0.0042	0.0031	0.0032	0.0027	0.0031	0.0024	0.0032	0.0029	0.0030	0.0030	0.0027
2015	0.0021	0.0033	0.0033	0.0027	0.0033	0.0028	0.0033	0.0030	0.0030	0.0030	0.0027
2016	0.0036	0.0035	0.0034	0.0027	0.0035	0.0026	0.0034	0.0031	0.0031	0.0031	0.0027
2017	0.0042	0.0037	0.0036	0.0027	0.0037	0.0029	0.0036	0.0032	0.0032	0.0032	0.0027
2018	0.0041	0.0039	0.0037	0.0027	0.0039	0.0032	0.0037	0.0034	0.0033	0.0033	0.0027
2019	NA	0.0041	0.0039	0.0027	0.0041	0.0034	0.0039	0.0035	0.0034	0.0034	0.0027
2020	NA	0.0043	0.0040	0.0027	0.0043	0.0034	0.0040	0.0036	0.0035	0.0035	0.0027
2021	NA	0.0046	0.0041	0.0027	0.0046	0.0034	0.0041	0.0037	0.0035	0.0035	0.0027
2022	NA	0.0048	0.0043	0.0027	0.0048	0.0034	0.0043	0.0038	0.0036	0.0036	0.0027
2023	NA	0.0051	0.0044	0.0027	0.0051	0.0034	0.0044	0.0039	0.0037	0.0037	0.0027
2024	NA	0.0054	0.0045	0.0027	0.0054	0.0034	0.0045	0.0041	0.0038	0.0038	0.0027
2025	NA	0.0056	0.0047	0.0027	0.0056	0.0034	0.0047	0.0042	0.0039	0.0039	0.0027
2026	NA	0.0060	0.0048	0.0027	0.0060	0.0034	0.0048	0.0043	0.0040	0.0040	0.0027
2027	NA	0.0063	0.0050	0.0027	0.0063	0.0034	0.0050	0.0045	0.0041	0.0041	0.0027
2028	NA	0.0066	0.0051	0.0027	0.0066	0.0034	0.0051	0.0046	0.0041	0.0041	0.0027

AIC COMPARISON GRAPH



LL-Based Comparison Table

Model	Compact LL	Likelihood	AIC*	BIC	HQ	AMSE
A,M,N	89.0720	88.5497	-170.144	-167.054	-169.986	8.6E-07
A,A,N	88.9285	88.4062	-169.857	-166.767	-169.699	8.8E-07
M,N,N	86.0758	85.5535	-168.152	-166.606	-168.072	1.1E-06
A,MD,N	89.0720	88.5497	-168.144	-164.281	-167.946	8.6E-07

A,N,N	85.9615	85.4392	-167.923	-166.378	-167.844	1.3E-06
A,AD,N	88.9285	88.4062	-167.857	-163.994	-167.659	8.8E-07
M,M,N	87.5596	87.0373	-167.119	-164.029	-166.961	8.9E-07
M,A,N	87.5234	87.0011	-167.047	-163.956	-166.889	9.0E-07
M,AD,N	87.5234	87.0011	-165.047	-161.184	-164.849	9.0E-07
M,MD,N	86.0758	85.5535	-162.152	-158.289	-161.954	1.1E-06

Summary of Model Selection Outputs, Metal Nonmetal Nonfatal Days Lost Incident Rate

The fully automatic method of ETS fails automatic selection of seasonality as the time series is too short. Manually executing the ETS procedure with the seasonality set to additive, multiplicative, and none start with different estimated parameters but conclude modeling with the same output. The AIC difference is attributable to the difference in the number of parameters. Given the same output errors, the simpler M,A,N is the model selected to represent the NFDL incident forecast.

ETS Smoothing Original series: MNFDL_IR Sample: 2003 2018 Included observations: 16 Model: M,A,A - Multiplicative Error, Additive Trend, Additive Season (Auto E=*, T=*) Model selection: Akaike Information Criterion Convergence achieved on boundaries. Parameters	ETS Smoothing Original series: MNFDL_IR Sample: 2003 2018 Included observations: 16 Model: M,A,M - Multiplicative Error, Additive Trend, Multiplicative Season (Auto E=*, T=*) Model selection: Akaike Information Criterion Convergence achieved on boundaries.	ETS Smoothing Original series: MNFDL_IR Sample: 2003 2030 Included observations: 16 Model: M,A,N - Multiplicative Error, Additive Trend, No Season (Auto E=*, T=*) Model selection: Akaike Information Criterion Convergence achieved on boundaries. Parameters

Alpha:	0.000000
Beta:	0.000000
Gamma:	0.000000
Initial Parameters	
Initial level:	0.040496
Initial trend:	-0.001417
Initial state 1:	0.000000
Compact Log-likelihood	62.38994
Log-likelihood	61.86764
Akaike Information Criterion	-114.7799
Schwarz Criterion	-110.9169
Hannan-Quinn Criterion	-114.5821
Sum of Squared Residuals	0.535744
Root Mean Squared Error	0.182986
Average Mean Squared Error	2.90E-05

Parameters	
Alpha:	0.000000
Beta:	0.000000
Gamma:	0.000000
Initial Parameters	
Initial level:	0.040496
Initial trend:	-0.001417
Initial state 1:	1.000000
Compact Log-likelihood	62.38994
Log-likelihood	61.86764
Akaike Information Criterion	-114.7799
Schwarz Criterion	-110.9169
Hannan-Quinn Criterion	-114.5821
Sum of Squared Residuals	0.535744
Root Mean Squared Error	0.182986
Average Mean Squared Error	2.90E-05

Alpha:	0.000000
Beta:	0.000000
Initial Parameters	
Initial level:	0.040496
Initial trend:	-0.001417
Compact Log-likelihood	62.38994
Log-likelihood	61.86764
Akaike Information Criterion	-116.7799
Schwarz Criterion	-113.6895
Hannan-Quinn Criterion	-116.6216
Sum of Squared Residuals	0.535744
Root Mean Squared Error	0.182986
Average Mean Squared Error	2.90E-05

Metal Nonmetal NFDL, Automatic Trend and Error, Additive Seasonal

ESTIMATION OUTPUT

ETS Smoothing
Original series: MNFDL_IR
Sample: 2003 2018
Included observations: 16
Model: M,A,A - Multiplicative Error, Additive Trend,
Additive Season (Auto E=*, T=*)
Model selection: Akaike Information Criterion
Convergence achieved on boundaries.

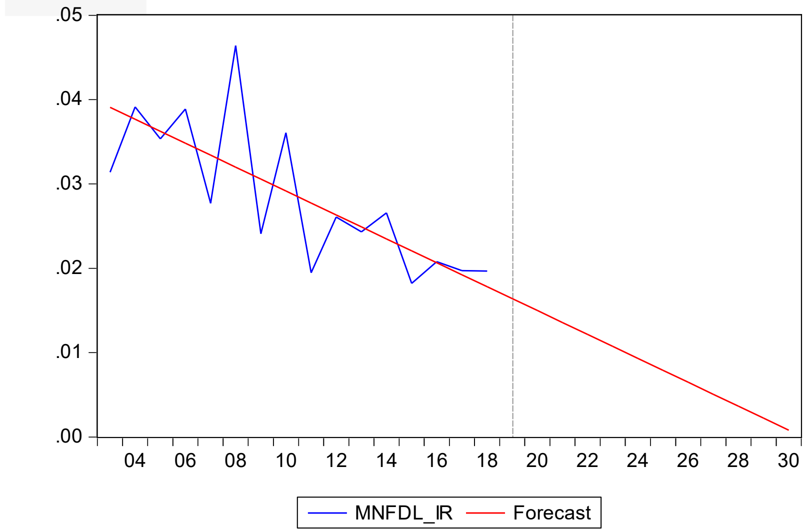
Parameters	
Alpha:	0.000000
Beta:	0.000000
Gamma:	0.000000

Initial Parameters	
Initial level:	0.040496
Initial trend:	-0.001417
Initial state 1:	0.000000

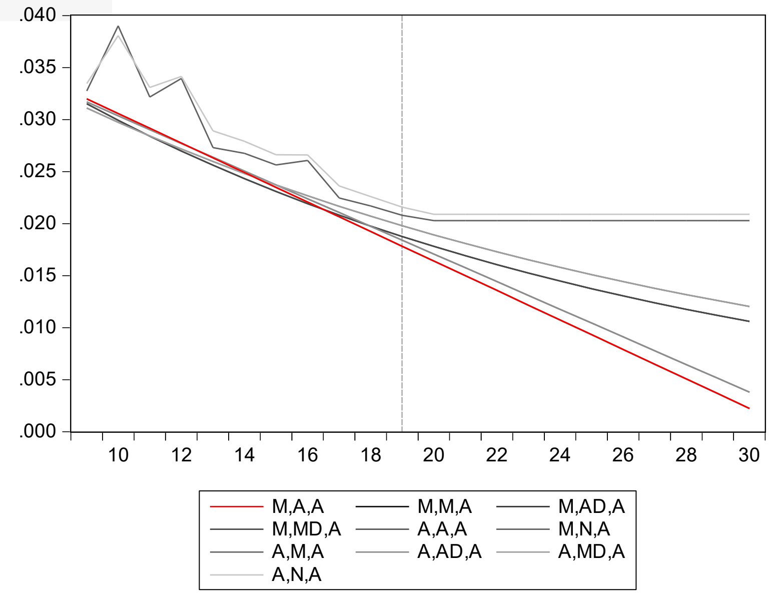
Compact Log-likelihood	62.38994
Log-likelihood	61.86764
Akaike Information Criterion	-114.7799
Schwarz Criterion	-110.9169
Hannan-Quinn Criterion	-114.5821
Sum of Squared Residuals	0.535744
Root Mean Squared Error	0.182986

Average Mean Squared Error	2.90E-05

Decomposition Graph



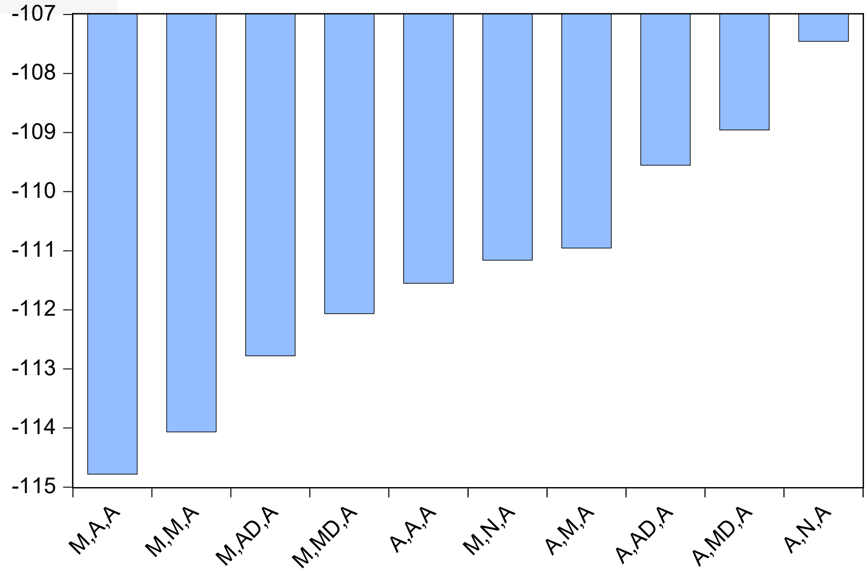
Forecast Comparison Graph



FORECAST COMPARISON TABLE

	Actuals	M,A,A	M,M,A	M,AD,A	M,MD,A	A,A,A	M,N,A	A,M,A	A,AD,A	A,MD,A	A,N,A
2003	0.0314	0.0391	0.0408	0.0391	0.0408	0.0383	0.0334	0.0390	0.0383	0.0390	0.0345
2004	0.0391	0.0377	0.0388	0.0377	0.0388	0.0370	0.0325	0.0373	0.0370	0.0373	0.0334
2005	0.0353	0.0362	0.0368	0.0362	0.0368	0.0357	0.0355	0.0356	0.0357	0.0356	0.0354
2006	0.0389	0.0348	0.0350	0.0348	0.0350	0.0343	0.0354	0.0341	0.0343	0.0341	0.0354
2007	0.0277	0.0334	0.0332	0.0334	0.0332	0.0330	0.0370	0.0326	0.0330	0.0326	0.0366
2008	0.0464	0.0320	0.0315	0.0320	0.0315	0.0317	0.0328	0.0311	0.0317	0.0311	0.0335
2009	0.0241	0.0306	0.0299	0.0306	0.0299	0.0304	0.0390	0.0297	0.0304	0.0297	0.0381
2010	0.0361	0.0292	0.0284	0.0292	0.0284	0.0290	0.0322	0.0284	0.0290	0.0284	0.0331
2011	0.0195	0.0277	0.0270	0.0277	0.0270	0.0277	0.0340	0.0272	0.0277	0.0272	0.0342
2012	0.0261	0.0263	0.0256	0.0263	0.0256	0.0264	0.0273	0.0260	0.0264	0.0260	0.0289
2013	0.0243	0.0249	0.0243	0.0249	0.0243	0.0250	0.0267	0.0248	0.0250	0.0248	0.0279
2014	0.0266	0.0235	0.0231	0.0235	0.0231	0.0237	0.0256	0.0237	0.0237	0.0237	0.0266
2015	0.0182	0.0221	0.0219	0.0221	0.0219	0.0224	0.0261	0.0227	0.0224	0.0227	0.0266
2016	0.0208	0.0207	0.0208	0.0207	0.0208	0.0211	0.0225	0.0217	0.0211	0.0217	0.0236
2017	0.0197	0.0192	0.0198	0.0192	0.0198	0.0197	0.0217	0.0207	0.0197	0.0207	0.0226
2018	0.0197	0.0178	0.0188	0.0178	0.0188	0.0184	0.0208	0.0198	0.0184	0.0198	0.0216
2019	NA	0.0164	0.0178	0.0164	0.0178	0.0171	0.0203	0.0189	0.0171	0.0189	0.0209
2020	NA	0.0150	0.0169	0.0150	0.0169	0.0157	0.0203	0.0181	0.0157	0.0181	0.0209
2021	NA	0.0136	0.0161	0.0136	0.0161	0.0144	0.0203	0.0173	0.0144	0.0173	0.0209
2022	NA	0.0122	0.0152	0.0122	0.0152	0.0131	0.0203	0.0165	0.0131	0.0165	0.0209
2023	NA	0.0107	0.0145	0.0107	0.0145	0.0118	0.0203	0.0158	0.0118	0.0158	0.0209
2024	NA	0.0093	0.0137	0.0093	0.0137	0.0104	0.0203	0.0151	0.0104	0.0151	0.0209
2025	NA	0.0079	0.0130	0.0079	0.0130	0.0091	0.0203	0.0144	0.0091	0.0144	0.0209
2026	NA	0.0065	0.0124	0.0065	0.0124	0.0078	0.0203	0.0138	0.0078	0.0138	0.0209
2027	NA	0.0051	0.0118	0.0051	0.0118	0.0064	0.0203	0.0132	0.0064	0.0132	0.0209
2028	NA	0.0036	0.0112	0.0036	0.0112	0.0051	0.0203	0.0126	0.0051	0.0126	0.0209

AIC COMPARISON GRAPH



LL-Based Comparison Table

Model	Compact LL	Likelihood	AIC*	BIC	HQ	AMSE
M,A,A	62.3899	61.8676	-114.780	-110.917	-114.582	2.9E-05
M,M,A	62.0325	61.5102	-114.065	-110.202	-113.867	3.0E-05
M,AD,A	62.3899	61.8676	-112.780	-108.144	-112.543	2.9E-05
M,MD,A	62.0325	61.5102	-112.065	-107.430	-111.828	3.0E-05

A,A, A	60.7757	60.2534	-111.551	-107.688	-111.354	2.9E-05
M,N, A	58.5803	58.0580	-111.161	-108.843	-111.042	5.3E-05
A,M, A	60.4778	59.9555	-110.956	-107.093	-110.758	3.0E-05
A,AD ,A	60.7757	60.2534	-109.551	-104.916	-109.314	NA
A,M D,A	60.4778	59.9555	-108.956	-104.320	-108.718	3.0E-05
A,N, A	56.7286	56.2063	-107.457	-105.139	-107.339	5.4E-05

Metal Nonmetal NFDL, Automatic Trend and Error, Multiplicative Seasonal

ESTIMATION OUTPUT

ETS Smoothing
Original series: MNFDL_IR
Sample: 2003 2018
Included observations: 16
Model: M,A,M - Multiplicative Error, Additive Trend,
Multiplicative Season (Auto E=*, T=*)
Model selection: Akaike Information Criterion
Convergence achieved on boundaries.

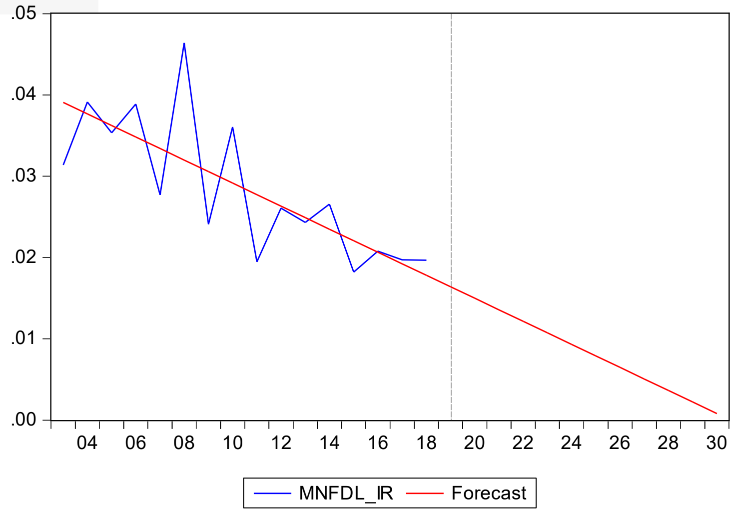
Parameters	
Alpha:	0.000000

Beta:	0.000000
Gamma:	0.000000

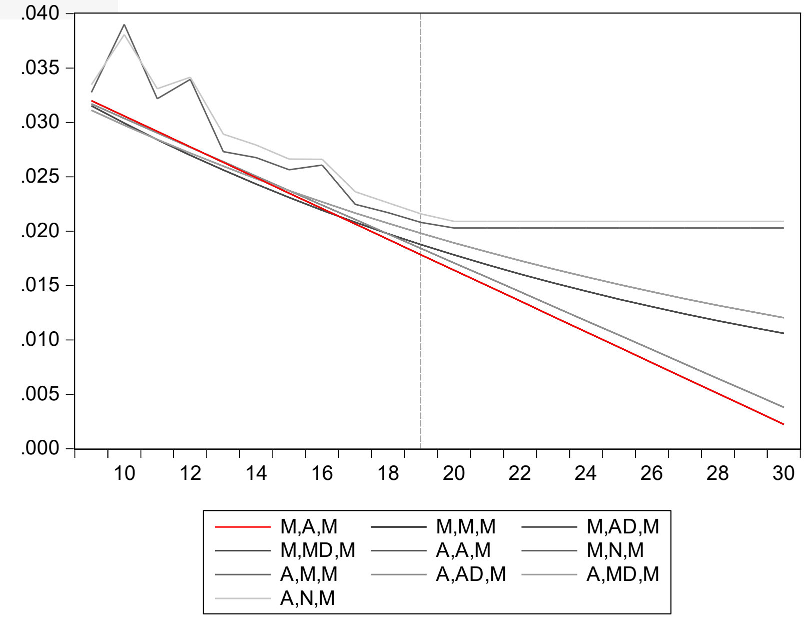
Initial Parameters	
Initial level:	0.040496
Initial trend:	-0.001417
Initial state 1:	1.000000

Compact Log-likelihood	62.38994
Log-likelihood	61.86764
Akaike Information Criterion	-114.7799
Schwarz Criterion	-110.9169
Hannan-Quinn Criterion	-114.5821
Sum of Squared Residuals	0.535744
Root Mean Squared Error	0.182986
Average Mean Squared Error	2.90E-05

Decomposition Graph



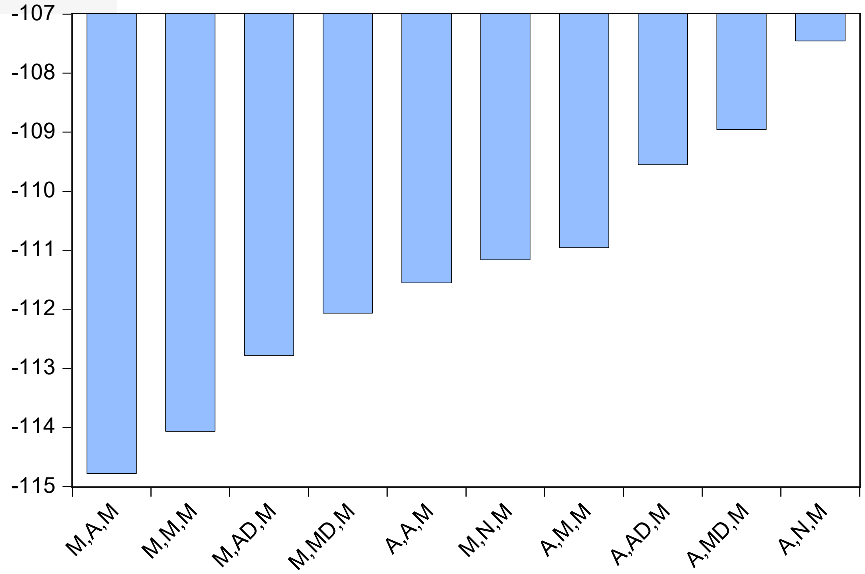
Forecast Comparison Graph



FORECAST COMPARISON TABLE

	Actuals	M,A,M	M,M,M	M,AD,M	M,MD,M	A,A,M	M,N,M	A,M,M	A,AD,M	A,MD,M	A,N,M
2003	0.0314	0.0391	0.0408	0.0391	0.0408	0.0383	0.0334	0.0390	0.0383	0.0390	0.0345
2004	0.0391	0.0377	0.0388	0.0377	0.0388	0.0370	0.0325	0.0373	0.0370	0.0373	0.0334
2005	0.0353	0.0362	0.0368	0.0362	0.0368	0.0357	0.0355	0.0356	0.0357	0.0356	0.0354
2006	0.0389	0.0348	0.0350	0.0348	0.0350	0.0343	0.0354	0.0341	0.0343	0.0341	0.0354
2007	0.0277	0.0334	0.0332	0.0334	0.0332	0.0330	0.0370	0.0326	0.0330	0.0326	0.0366
2008	0.0464	0.0320	0.0315	0.0320	0.0315	0.0317	0.0328	0.0311	0.0317	0.0311	0.0335
2009	0.0241	0.0306	0.0299	0.0306	0.0299	0.0304	0.0390	0.0297	0.0304	0.0297	0.0381
2010	0.0361	0.0292	0.0284	0.0292	0.0284	0.0290	0.0322	0.0284	0.0290	0.0284	0.0331
2011	0.0195	0.0277	0.0270	0.0277	0.0270	0.0277	0.0340	0.0272	0.0277	0.0272	0.0342
2012	0.0261	0.0263	0.0256	0.0263	0.0256	0.0264	0.0273	0.0260	0.0264	0.0260	0.0289
2013	0.0243	0.0249	0.0243	0.0249	0.0243	0.0250	0.0267	0.0248	0.0250	0.0248	0.0279
2014	0.0266	0.0235	0.0231	0.0235	0.0231	0.0237	0.0256	0.0237	0.0237	0.0237	0.0266
2015	0.0182	0.0221	0.0219	0.0221	0.0219	0.0224	0.0261	0.0227	0.0224	0.0227	0.0266
2016	0.0208	0.0207	0.0208	0.0207	0.0208	0.0211	0.0225	0.0217	0.0211	0.0217	0.0236
2017	0.0197	0.0192	0.0198	0.0192	0.0198	0.0197	0.0217	0.0207	0.0197	0.0207	0.0226
2018	0.0197	0.0178	0.0188	0.0178	0.0188	0.0184	0.0208	0.0198	0.0184	0.0198	0.0216
2019	NA	0.0164	0.0178	0.0164	0.0178	0.0171	0.0203	0.0189	0.0171	0.0189	0.0209
2020	NA	0.0150	0.0169	0.0150	0.0169	0.0157	0.0203	0.0181	0.0157	0.0181	0.0209
2021	NA	0.0136	0.0161	0.0136	0.0161	0.0144	0.0203	0.0173	0.0144	0.0173	0.0209
2022	NA	0.0122	0.0152	0.0122	0.0152	0.0131	0.0203	0.0165	0.0131	0.0165	0.0209
2023	NA	0.0107	0.0145	0.0107	0.0145	0.0118	0.0203	0.0158	0.0118	0.0158	0.0209
2024	NA	0.0093	0.0137	0.0093	0.0137	0.0104	0.0203	0.0151	0.0104	0.0151	0.0209
2025	NA	0.0079	0.0130	0.0079	0.0130	0.0091	0.0203	0.0144	0.0091	0.0144	0.0209
2026	NA	0.0065	0.0124	0.0065	0.0124	0.0078	0.0203	0.0138	0.0078	0.0138	0.0209
2027	NA	0.0051	0.0118	0.0051	0.0118	0.0064	0.0203	0.0132	0.0064	0.0132	0.0209
2028	NA	0.0036	0.0112	0.0036	0.0112	0.0051	0.0203	0.0126	0.0051	0.0126	0.0209

AIC COMPARISON GRAPH



LL-Based Comparison Table

Model	Compact LL	Likelihood	AIC*	BIC	HQ	AMSE
M,A,M	62.3899	61.8676	-114.780	-110.917	-114.582	2.9E-05
M,M,M	62.0325	61.5102	-114.065	-110.202	-113.867	3.0E-05
M,AD,M	62.3899	61.8676	-112.780	-108.144	-112.543	NA
M,MD,M	62.0325	61.5102	-112.065	-107.430	-111.828	3.0E-05
A,A,M	60.7757	60.2534	-111.551	-107.688	-111.354	2.9E-05

M,N,M	58.5803	58.0580	-111.161	-108.843	-111.042	5.3E-05
A,M,M	60.4778	59.9555	-110.956	-107.093	-110.758	3.0E-05
A,AD,M	60.7757	60.2534	-109.551	-104.916	-109.314	NA
A,MD,M	60.4778	59.9555	-108.956	-104.320	-108.718	3.0E-05
A,N,M	56.7286	56.2063	-107.457	-105.139	-107.339	5.4E-05

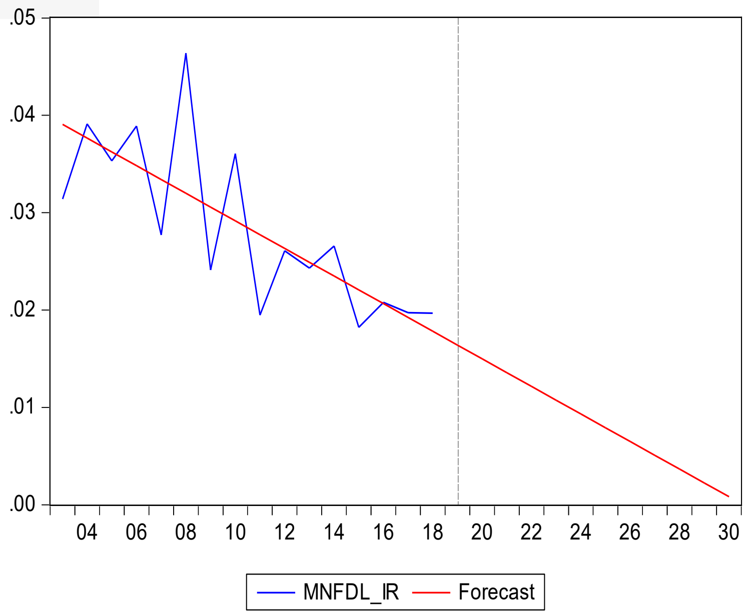
Metal Nonmetal NFDL, Automatic Trend and Error, No Seasonal

ESTIMATION OUTPUT

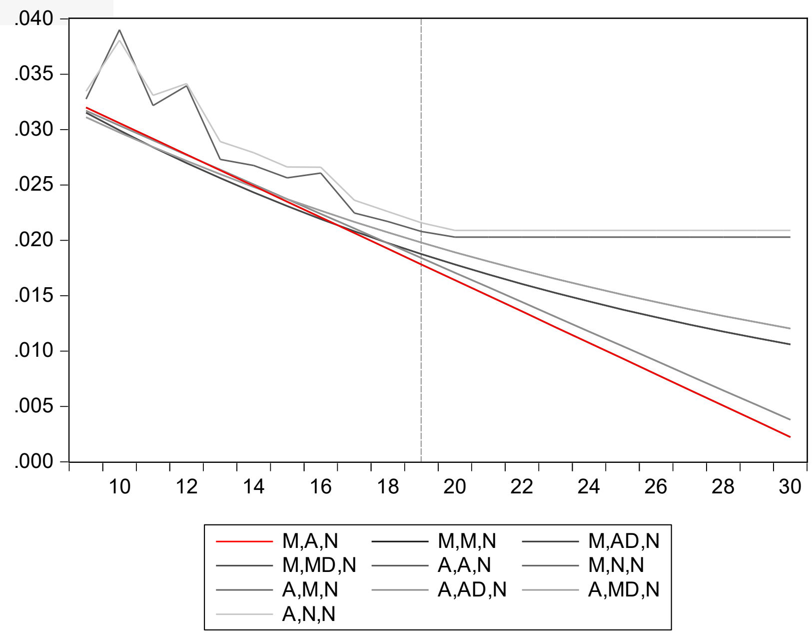
ETS Smoothing
Original series: MNFDL_IR
Sample: 2003 2030
Included observations: 16
Model: M,A,N - Multiplicative Error,
Additive Trend,
No Season (Auto E=*, T=*)
Model selection: Akaike Information
Criterion
Convergence achieved on boundaries.

Parameters	
Alpha:	0.000000
Beta:	0.000000
Initial Parameters	
Initial level:	0.040496
Initial trend:	-0.001417
Compact Log-likelihood	62.38994
Log-likelihood	61.86764
Akaike Information Criterion	-116.7799
Schwarz Criterion	-113.6895
Hannan-Quinn Criterion	-116.6216
Sum of Squared Residuals	0.535744
Root Mean Squared Error	0.182986
Average Mean Squared Error	2.90E-05

Decomposition Graph



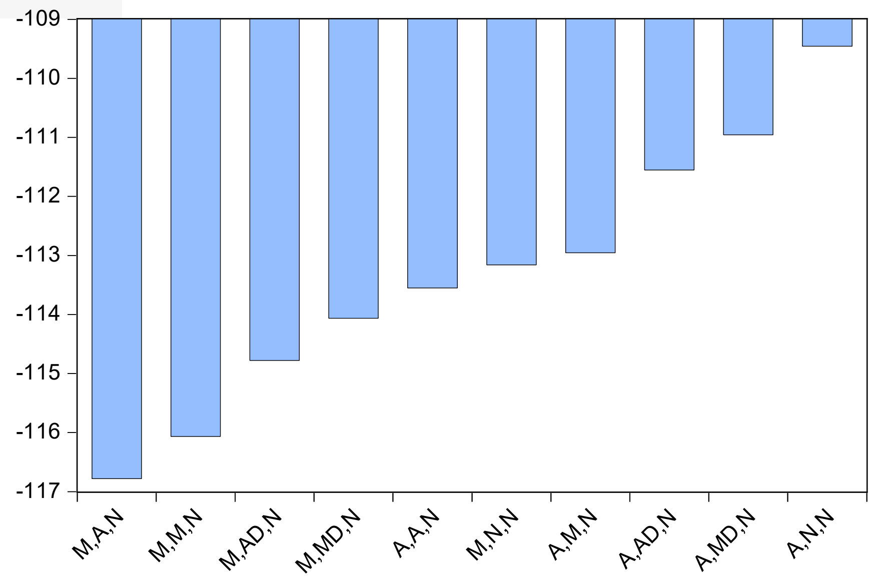
Forecast Comparison Graph



FORECAST COMPARISON TABLE

	Actuals	M,A,N	M,M,N	M,AD,N	M,MD,N	A,A,N	M,N,N	A,M,N	A,AD,N	A,MD,N	A,N,N
2003	0.0314	0.0391	0.0408	0.0391	0.0408	0.0383	0.0334	0.0390	0.0383	0.0390	0.0345
2004	0.0391	0.0377	0.0388	0.0377	0.0388	0.0370	0.0325	0.0373	0.0370	0.0373	0.0334
2005	0.0353	0.0362	0.0368	0.0362	0.0368	0.0357	0.0355	0.0356	0.0357	0.0356	0.0354
2006	0.0389	0.0348	0.0350	0.0348	0.0350	0.0343	0.0354	0.0341	0.0343	0.0341	0.0354
2007	0.0277	0.0334	0.0332	0.0334	0.0332	0.0330	0.0370	0.0326	0.0330	0.0326	0.0366
2008	0.0464	0.0320	0.0315	0.0320	0.0315	0.0317	0.0328	0.0311	0.0317	0.0311	0.0335
2009	0.0241	0.0306	0.0299	0.0306	0.0299	0.0304	0.0390	0.0297	0.0304	0.0297	0.0381
2010	0.0361	0.0292	0.0284	0.0292	0.0284	0.0290	0.0322	0.0284	0.0290	0.0284	0.0331
2011	0.0195	0.0277	0.0270	0.0277	0.0270	0.0277	0.0340	0.0272	0.0277	0.0272	0.0342
2012	0.0261	0.0263	0.0256	0.0263	0.0256	0.0264	0.0273	0.0260	0.0264	0.0260	0.0289
2013	0.0243	0.0249	0.0243	0.0249	0.0243	0.0250	0.0267	0.0248	0.0250	0.0248	0.0279
2014	0.0266	0.0235	0.0231	0.0235	0.0231	0.0237	0.0256	0.0237	0.0237	0.0237	0.0266
2015	0.0182	0.0221	0.0219	0.0221	0.0219	0.0224	0.0261	0.0227	0.0224	0.0227	0.0266
2016	0.0208	0.0207	0.0208	0.0207	0.0208	0.0211	0.0225	0.0217	0.0211	0.0217	0.0236
2017	0.0197	0.0192	0.0198	0.0192	0.0198	0.0197	0.0217	0.0207	0.0197	0.0207	0.0226
2018	0.0197	0.0178	0.0188	0.0178	0.0188	0.0184	0.0208	0.0198	0.0184	0.0198	0.0216
2019	NA	0.0164	0.0178	0.0164	0.0178	0.0171	0.0203	0.0189	0.0171	0.0189	0.0209
2020	NA	0.0150	0.0169	0.0150	0.0169	0.0157	0.0203	0.0181	0.0157	0.0181	0.0209
2021	NA	0.0136	0.0161	0.0136	0.0161	0.0144	0.0203	0.0173	0.0144	0.0173	0.0209
2022	NA	0.0122	0.0152	0.0122	0.0152	0.0131	0.0203	0.0165	0.0131	0.0165	0.0209
2023	NA	0.0107	0.0145	0.0107	0.0145	0.0118	0.0203	0.0158	0.0118	0.0158	0.0209
2024	NA	0.0093	0.0137	0.0093	0.0137	0.0104	0.0203	0.0151	0.0104	0.0151	0.0209
2025	NA	0.0079	0.0130	0.0079	0.0130	0.0091	0.0203	0.0144	0.0091	0.0144	0.0209
2026	NA	0.0065	0.0124	0.0065	0.0124	0.0078	0.0203	0.0138	0.0078	0.0138	0.0209
2027	NA	0.0051	0.0118	0.0051	0.0118	0.0064	0.0203	0.0132	0.0064	0.0132	0.0209
2028	NA	0.0036	0.0112	0.0036	0.0112	0.0051	0.0203	0.0126	0.0051	0.0126	0.0209

AIC COMPARISON GRAPH



LL-Based Comparison Table

Model	Compact LL	Likelihood	AIC*	BIC	HQ	AMSE
M,A,N	62.3899	61.8676	-116.780	-113.690	-116.622	2.9E-05
M,M,N	62.0325	61.5102	-116.065	-112.975	-115.907	3.0E-05
M,AD,N	62.3899	61.8676	-114.780	-110.917	-114.582	2.9E-05
M,MD,N	62.0325	61.5102	-114.065	-110.202	-113.867	3.0E-05
A,A,N	60.7757	60.2534	-113.551	-110.461	-113.393	2.9E-05
M,N,N	58.5803	58.0580	-113.161	-111.615	-113.081	5.3E-05

A,M,N	60.4778	59.9555	-112.956	-109.865	-112.797	3.0E-05
A,AD, N	60.7757	60.2534	-111.551	-107.688	-111.354	2.9E-05
A,MD, N	60.4778	59.9555	-110.956	-107.093	-110.758	3.0E-05
A,N,N	56.7286	56.2063	-109.457	-107.912	-109.378	5.4E-05

Summary of Model Selection Outputs, Metal Nonmetal No Days Lost Incident Rate

The fully automatic method of ETS fails automatic selection of seasonality as the time series is too short. Manually executing the ETS procedure with the seasonality set to additive, multiplicative, and none start with different estimated parameters but conclude modeling with the similar outputs. The M,N,A and the M,N,N produce the same output. The AIC difference is attributable to the difference in the number of parameters. Given the same output errors for the two, the single parameter M,N,N is the model selected to represent the NFDL incident forecast.

ETS Smoothing
Original series: MNDL_IR
Sample: 2003 2030
Included observations: 16
Model: M,N,A - Multiplicative Error, No Trend,
Additive Season (Auto E=*, T=*)
Model selection: Akaike Information Criterion
Convergence achieved after 8 iterations

Parameters	
Alpha:	0.527324
Gamma:	0.228525
Initial Parameters	

ETS Smoothing
Original series: MNDL_IR
Sample: 2003 2018
Included observations: 16
Model: M,N,M - Multiplicative Error, No Trend,
Multiplicative Season (Auto E=*, T=*)
Model selection: Akaike Information Criterion
Convergence achieved after 19 iterations

Parameters	
Alpha:	0.403331
Gamma:	0.403330
Initial Parameters	

ETS Smoothing
Original series: MNDL_IR
Sample: 2003 2018
Included observations: 16
Model: M,N,N - Multiplicative Error, No Trend, No
Season (Auto E=*, T=*)
Model selection: Akaike Information Criterion
Convergence achieved after 8 iterations

Parameters	
Alpha:	0.755850
Initial Parameters	
Initial level:	0.014772

Initial level:	0.014772
Initial state 1:	0.000000
Compact Log-likelihood	69.51683
Log-likelihood	68.99452
Akaike Information Criterion	-133.0337
Schwarz Criterion	-130.7159
Hannan-Quinn Criterion	-132.9150
Sum of Squared Residuals	1.028446
Root Mean Squared Error	0.253531
Average Mean Squared Error	1.83E-05

Initial level:	0.014555
Initial state 1:	1.000000
Compact Log-likelihood	69.57219
Log-likelihood	69.04989
Akaike Information Criterion	-133.1444
Schwarz Criterion	-130.8266
Hannan-Quinn Criterion	-133.0257
Sum of Squared Residuals	1.005339
Root Mean Squared Error	0.250667
Average Mean Squared Error	1.92E-05

Compact Log-likelihood	69.51683
Log-likelihood	68.99452
Akaike Information Criterion	-135.0337
Schwarz Criterion	-133.4885
Hannan-Quinn Criterion	-134.9545
Sum of Squared Residuals	1.028446
Root Mean Squared Error	0.253531
Average Mean Squared Error	1.83E-05

Metal Nonmetal No Days Lost, Automatic Trend and Error, Additive Seasonal

MODEL SUMMARY

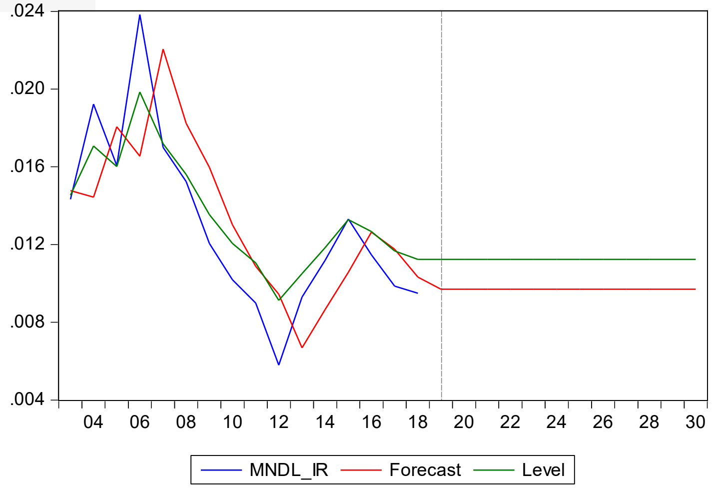
ETS Smoothing
Original series: MNDL_IR
Sample: 2003 2030
Included observations: 16
Model: M,N,A - Multiplicative Error, No Trend,
Additive Season (Auto E=*, T=*)
Model selection: Akaike Information Criterion
Convergence achieved after 8 iterations

Parameters	
Alpha:	0.527324
Gamma:	0.228525

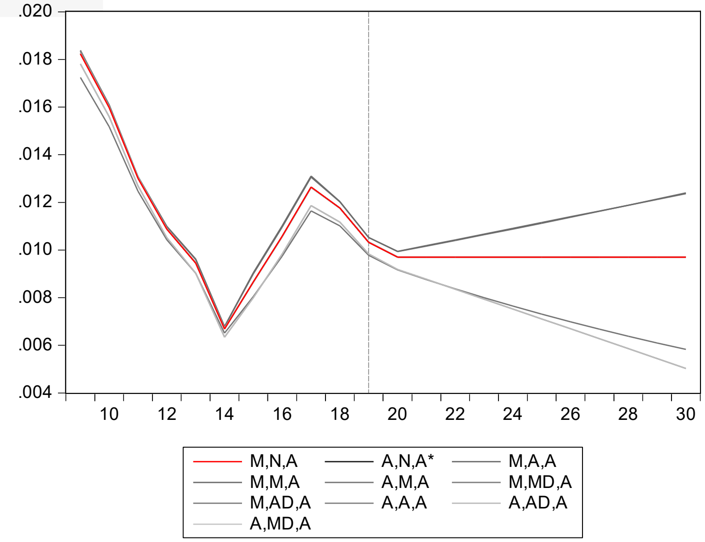
Initial Parameters	
Initial level:	0.014772
Initial state 1:	0.000000

Compact Log-likelihood	69.51683
Log-likelihood	68.99452
Akaike Information Criterion	-133.0337
Schwarz Criterion	-130.7159
Hannan-Quinn Criterion	-132.9150
Sum of Squared Residuals	1.028446
Root Mean Squared Error	0.253531
Average Mean Squared Error	1.83E-05

Decomposition Graph



Forecast Comparison Graph

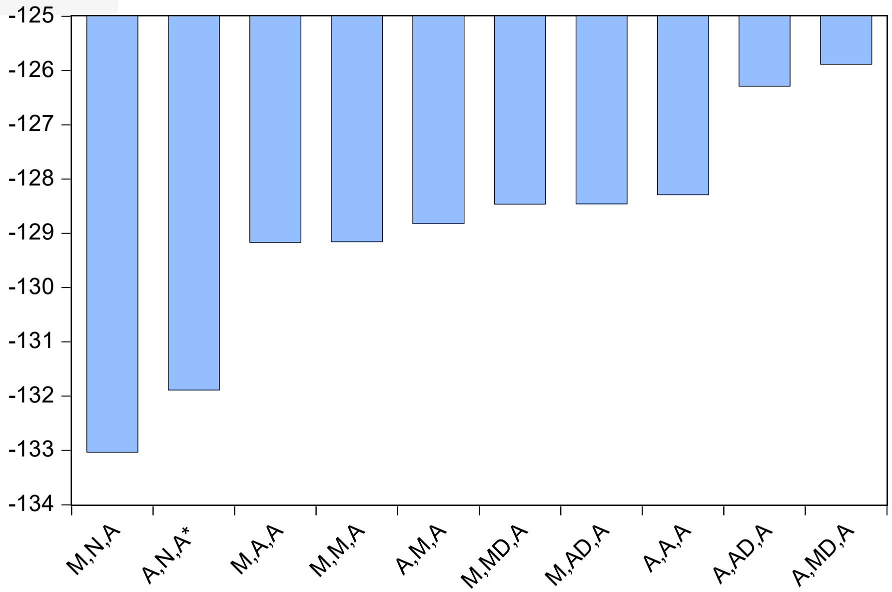


FORECAST COMPARISON TABLE

	Actuals	M,N,A	A,N,A*	M,A,A	M,M,A	A,M,A	M,MD,A	M,AD,A	A,A,A	A,AD,A	A,MD,A
2003	0.0143	0.0148	0.0155	0.0144	0.0145	0.0160	0.0136	0.0136	0.0158	0.0158	0.0155
2004	0.0192	0.0144	0.0146	0.0146	0.0146	0.0142	0.0178	0.0178	0.0144	0.0144	0.0146
2005	0.0161	0.0181	0.0181	0.0186	0.0185	0.0169	0.0202	0.0201	0.0174	0.0174	0.0181
2006	0.0238	0.0166	0.0166	0.0168	0.0167	0.0156	0.0175	0.0175	0.0160	0.0160	0.0166
2007	0.0170	0.0221	0.0220	0.0227	0.0226	0.0203	0.0224	0.0224	0.0211	0.0211	0.0220
2008	0.0152	0.0182	0.0183	0.0184	0.0183	0.0172	0.0184	0.0184	0.0178	0.0178	0.0183
2009	0.0121	0.0160	0.0160	0.0161	0.0161	0.0152	0.0160	0.0160	0.0156	0.0156	0.0160
2010	0.0102	0.0130	0.0130	0.0131	0.0131	0.0125	0.0130	0.0130	0.0127	0.0127	0.0130
2011	0.0090	0.0109	0.0109	0.0110	0.0110	0.0104	0.0109	0.0109	0.0105	0.0105	0.0109
2012	0.0058	0.0094	0.0095	0.0096	0.0096	0.0090	0.0095	0.0095	0.0090	0.0090	0.0095
2013	0.0093	0.0067	0.0067	0.0068	0.0068	0.0065	0.0067	0.0067	0.0063	0.0063	0.0067
2014	0.0112	0.0087	0.0087	0.0090	0.0090	0.0080	0.0087	0.0087	0.0080	0.0080	0.0087
2015	0.0133	0.0106	0.0106	0.0110	0.0110	0.0097	0.0106	0.0106	0.0098	0.0098	0.0106
2016	0.0115	0.0126	0.0126	0.0131	0.0131	0.0116	0.0126	0.0126	0.0119	0.0119	0.0126
2017	0.0099	0.0118	0.0118	0.0120	0.0120	0.0110	0.0118	0.0118	0.0112	0.0112	0.0118
2018	0.0095	0.0103	0.0103	0.0105	0.0105	0.0098	0.0103	0.0103	0.0098	0.0098	0.0103
2019	NA	0.0097	0.0097	0.0099	0.0099	0.0092	0.0097	0.0097	0.0092	0.0092	0.0097
2020	NA	0.0097	0.0097	0.0102	0.0102	0.0088	0.0097	0.0097	0.0088	0.0088	0.0097
2021	NA	0.0097	0.0097	0.0104	0.0104	0.0084	0.0097	0.0097	0.0084	0.0084	0.0097
2022	NA	0.0097	0.0097	0.0107	0.0106	0.0080	0.0097	0.0097	0.0079	0.0079	0.0097
2023	NA	0.0097	0.0097	0.0109	0.0109	0.0076	0.0097	0.0097	0.0075	0.0075	0.0097
2024	NA	0.0097	0.0097	0.0112	0.0111	0.0073	0.0097	0.0097	0.0071	0.0071	0.0097
2025	NA	0.0097	0.0097	0.0114	0.0114	0.0070	0.0097	0.0097	0.0067	0.0067	0.0097
2026	NA	0.0097	0.0097	0.0116	0.0116	0.0067	0.0097	0.0097	0.0063	0.0063	0.0097
2027	NA	0.0097	0.0097	0.0119	0.0119	0.0064	0.0097	0.0097	0.0059	0.0059	0.0097
2028	NA	0.0097	0.0097	0.0121	0.0121	0.0061	0.0097	0.0097	0.0054	0.0054	0.0097

*1 model failed to converge

AIC COMPARISON GRAPH



LL-Based Comparison Table

Model	Compact LL	Likelihood	AIC*	BIC	HQ	AMSE
M,N,A	69.5168	68.9945	-133.034	-130.716	-132.915	1.8E-05
A,N,A *	68.9442	68.4219	-131.888	-129.571	-131.770	1.8E-05
M,A,A	69.5856	69.0633	-129.171	-125.308	-128.973	2.0E-05
M,M,A	69.5773	69.0550	-129.155	-125.292	-128.957	1.9E-05
A,M,A	69.4103	68.8880	-128.821	-124.958	-128.623	1.5E-05
M,MD,	70.2312	69.7089	-128.462	-123.827	-128.225	2.8E-05

A						
M,AD, A	70.2302	69.7078	-128.460	-123.825	-128.223	2.1E-05
A,A,A	69.1442	68.6219	-128.288	-124.425	-128.090	1.7E-05
A,AD, A	69.1442	68.6219	-126.288	-121.653	-126.051	NA
A,MD, A	68.9442	68.4219	-125.888	-121.253	-125.651	1.8E-05

*1 model failed to converge

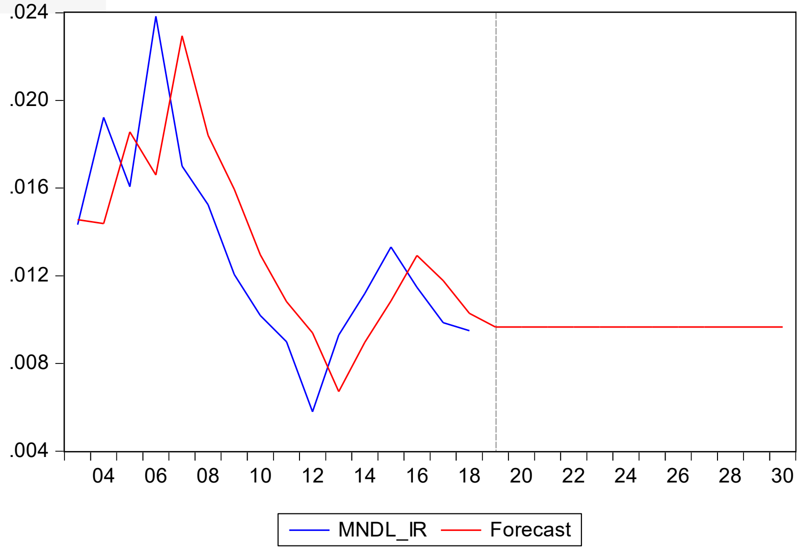
Metal Nonmetal No Days Lost, Automatic Trend and Error, Multiplicative Seasonal

MODEL SUMMARY

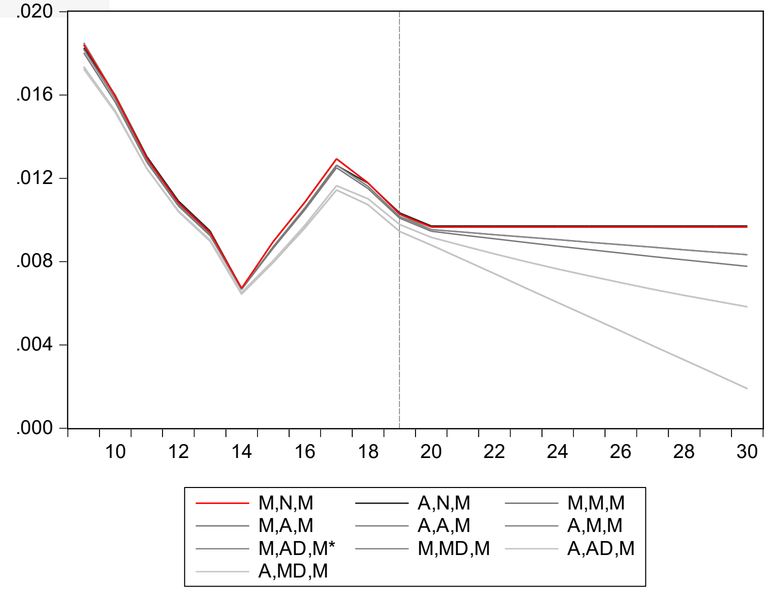
ETS Smoothing
Original series: MNDL_IR
Sample: 2003 2018
Included observations: 16
Model: M,N,M - Multiplicative Error, No Trend,
Multiplicative Season (Auto E=*, T=*)
Model selection: Akaike Information Criterion
Convergence achieved after 19 iterations

Parameters	
Alpha:	0.403331
Gamma:	0.403330
Initial Parameters	
Initial level:	0.014555
Initial state 1:	1.000000
Compact Log-likelihood	69.57219
Log-likelihood	69.04989
Akaike Information Criterion	-133.1444
Schwarz Criterion	-130.8266
Hannan-Quinn Criterion	-133.0257
Sum of Squared Residuals	1.005339
Root Mean Squared Error	0.250667
Average Mean Squared Error	1.92E-05

Decomposition Graph



Forecast Comparison Graph

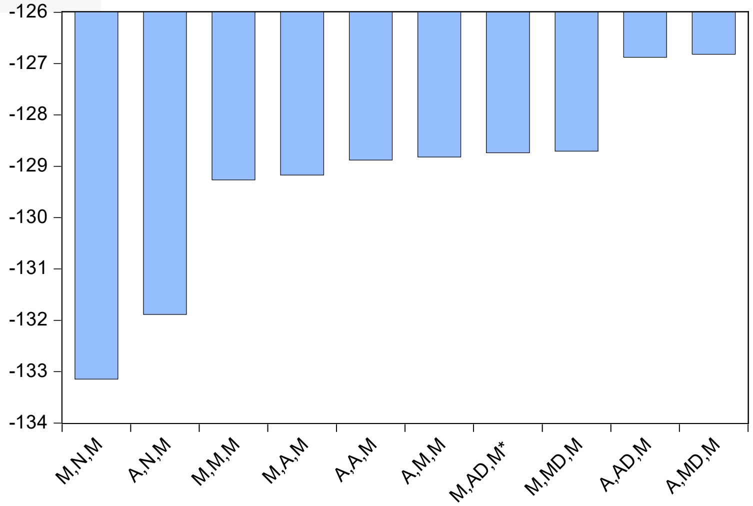


FORECAST COMPARISON TABLE

	Actuals	M,N,M	A,N,M	M,M,M	M,A,M	A,A,M	A,M,M	M,AD,M *	M,MD,M	A,AD,M	A,MD,M
2003	0.0143	0.0146	0.0155	0.0150	0.0148	0.0159	0.0160	0.0136	0.0136	0.0159	0.0160
2004	0.0192	0.0144	0.0146	0.0142	0.0143	0.0143	0.0142	0.0181	0.0180	0.0143	0.0142
2005	0.0161	0.0186	0.0181	0.0180	0.0182	0.0171	0.0169	0.0205	0.0205	0.0171	0.0169
2006	0.0238	0.0166	0.0166	0.0162	0.0164	0.0158	0.0156	0.0175	0.0175	0.0158	0.0156
2007	0.0170	0.0229	0.0220	0.0221	0.0224	0.0205	0.0203	0.0232	0.0232	0.0205	0.0203
2008	0.0152	0.0184	0.0183	0.0180	0.0182	0.0174	0.0172	0.0185	0.0185	0.0174	0.0172
2009	0.0121	0.0159	0.0160	0.0157	0.0158	0.0152	0.0152	0.0160	0.0160	0.0152	0.0152
2010	0.0102	0.0130	0.0130	0.0128	0.0129	0.0125	0.0125	0.0129	0.0130	0.0125	0.0125
2011	0.0090	0.0108	0.0109	0.0107	0.0107	0.0104	0.0104	0.0108	0.0108	0.0104	0.0104
2012	0.0058	0.0094	0.0095	0.0092	0.0093	0.0090	0.0090	0.0094	0.0094	0.0090	0.0090
2013	0.0093	0.0067	0.0067	0.0067	0.0067	0.0064	0.0065	0.0067	0.0067	0.0064	0.0065
2014	0.0112	0.0090	0.0087	0.0087	0.0087	0.0080	0.0080	0.0090	0.0090	0.0080	0.0080
2015	0.0133	0.0108	0.0106	0.0105	0.0106	0.0096	0.0097	0.0109	0.0109	0.0096	0.0097
2016	0.0115	0.0129	0.0126	0.0125	0.0126	0.0114	0.0116	0.0129	0.0129	0.0114	0.0116
2017	0.0099	0.0118	0.0118	0.0115	0.0116	0.0107	0.0110	0.0118	0.0118	0.0107	0.0110
2018	0.0095	0.0103	0.0103	0.0101	0.0102	0.0094	0.0098	0.0103	0.0103	0.0094	0.0098
2019	NA	0.0097	0.0097	0.0095	0.0095	0.0088	0.0092	0.0095	0.0097	0.0088	0.0092
2020	NA	0.0097	0.0097	0.0093	0.0094	0.0081	0.0088	0.0094	0.0097	0.0081	0.0088
2021	NA	0.0097	0.0097	0.0091	0.0093	0.0074	0.0084	0.0093	0.0097	0.0074	0.0084
2022	NA	0.0097	0.0097	0.0089	0.0092	0.0067	0.0080	0.0092	0.0097	0.0067	0.0080
2023	NA	0.0097	0.0097	0.0087	0.0090	0.0060	0.0076	0.0090	0.0097	0.0060	0.0076
2024	NA	0.0097	0.0097	0.0086	0.0089	0.0053	0.0073	0.0089	0.0097	0.0053	0.0073
2025	NA	0.0097	0.0097	0.0084	0.0088	0.0047	0.0070	0.0088	0.0097	0.0047	0.0070
2026	NA	0.0097	0.0097	0.0082	0.0087	0.0040	0.0067	0.0087	0.0097	0.0040	0.0067
2027	NA	0.0097	0.0097	0.0081	0.0086	0.0033	0.0064	0.0086	0.0097	0.0033	0.0064
2028	NA	0.0097	0.0097	0.0079	0.0084	0.0026	0.0061	0.0084	0.0097	0.0026	0.0061

*1 model failed to converge

AIC COMPARISON GRAPH



LL-Based Comparison Table

Model	Compact LL	Likelihood	AIC*	BIC	HQ	AMSE
M,N,M	69.5722	69.0499	-133.144	-130.827	-133.026	1.9E-05
A,N,M	68.9442	68.4219	-131.888	-129.571	-131.770	1.8E-05
M,M,M	69.6338	69.1115	-129.268	-125.405	-129.070	1.7E-05
M,A,M	69.5853	69.0630	-129.171	-125.308	-128.973	1.8E-05
A,A,M	69.4397	68.9174	-128.879	-125.017	-128.682	1.5E-05
A,M,M	69.4103	68.8880	-128.821	-124.958	-128.623	1.5E-05
M,AD, M*	70.3678	69.8455	-128.736	-124.100	-128.498	NA
M,MD, M	70.3521	69.8298	-128.704	-124.069	-128.467	2.8E-05
A,AD,	69.4397	68.9174	-126.879	-122.244	-126.642	1.5E-05

M A,MD, M	69.4103	68.8880	-126.821	-122.185	-126.583	1.5E-05

*1 Model Failed To Converge

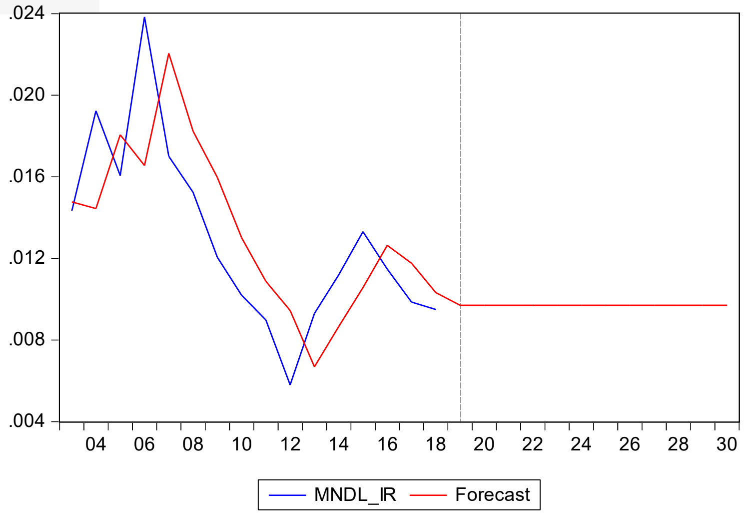
Metal Nonmetal No Days Lost, Automatic Trend and Error, No Seasonal

MODEL SUMMARY

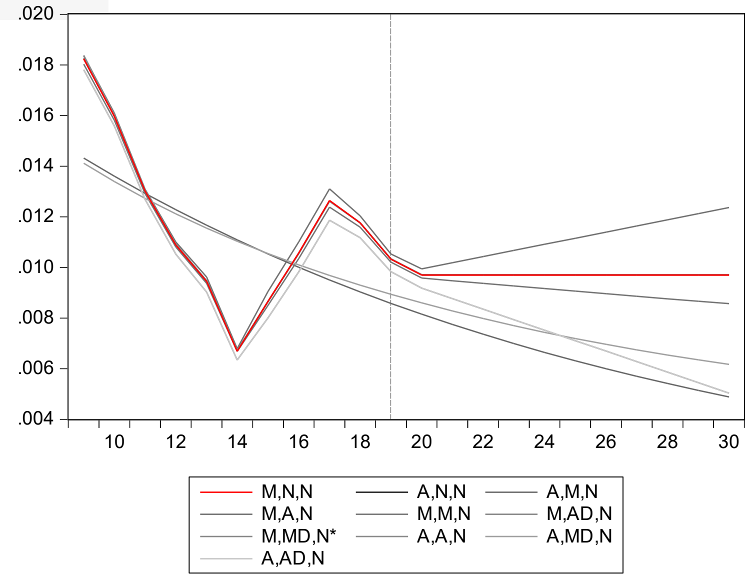
ETS Smoothing
Original series: MNDL_IR
Sample: 2003 2018
Included observations: 16
Model: M,N,N - Multiplicative Error, No Trend, No
Season (Auto E=*, T=*)
Model selection: Akaike Information Criterion
Convergence achieved after 8 iterations

Parameters	
Alpha:	0.755850
Initial Parameters	
Initial level:	0.014772
Compact Log-likelihood	69.51683
Log-likelihood	68.99452
Akaike Information Criterion	-135.0337
Schwarz Criterion	-133.4885
Hannan-Quinn Criterion	-134.9545
Sum of Squared Residuals	1.028446
Root Mean Squared Error	0.253531
Average Mean Squared Error	1.83E-05

Decomposition Graph



Forecast Comparison Graph

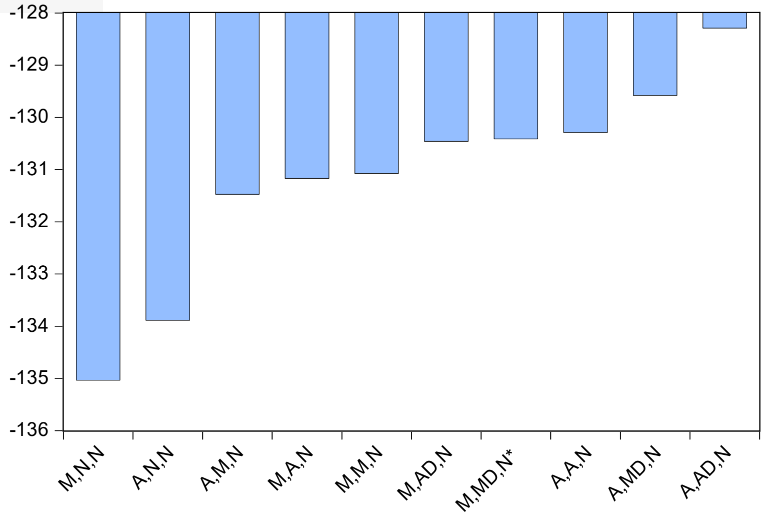


FORECAST COMPARISON TABLE

	Actuals	M,N,N	A,N,N	A,M,N	M,A,N	M,M,N	M,AD,N	M,MD,N *	A,A,N	A,MD,N	A,AD,N
2003	0.0143	0.0148	0.0155	0.0185	0.0144	0.0150	0.0136	0.0136	0.0158	0.0188	0.0158
2004	0.0192	0.0144	0.0146	0.0176	0.0146	0.0144	0.0178	0.0178	0.0144	0.0177	0.0144
2005	0.0161	0.0181	0.0181	0.0167	0.0186	0.0177	0.0201	0.0201	0.0174	0.0167	0.0174
2006	0.0238	0.0166	0.0166	0.0159	0.0168	0.0163	0.0175	0.0174	0.0160	0.0157	0.0160
2007	0.0170	0.0221	0.0220	0.0151	0.0227	0.0216	0.0224	0.0223	0.0211	0.0149	0.0211
2008	0.0152	0.0182	0.0183	0.0143	0.0184	0.0180	0.0184	0.0184	0.0178	0.0141	0.0178
2009	0.0121	0.0160	0.0160	0.0136	0.0161	0.0158	0.0160	0.0160	0.0156	0.0134	0.0156
2010	0.0102	0.0130	0.0130	0.0129	0.0131	0.0129	0.0130	0.0131	0.0127	0.0127	0.0127
2011	0.0090	0.0109	0.0109	0.0123	0.0110	0.0108	0.0109	0.0109	0.0105	0.0121	0.0105
2012	0.0058	0.0094	0.0095	0.0117	0.0096	0.0094	0.0095	0.0095	0.0090	0.0116	0.0090
2013	0.0093	0.0067	0.0067	0.0111	0.0068	0.0067	0.0067	0.0067	0.0063	0.0110	0.0063
2014	0.0112	0.0087	0.0087	0.0105	0.0090	0.0085	0.0087	0.0086	0.0080	0.0105	0.0080
2015	0.0133	0.0106	0.0106	0.0100	0.0110	0.0103	0.0106	0.0105	0.0098	0.0101	0.0098
2016	0.0115	0.0126	0.0126	0.0095	0.0131	0.0124	0.0126	0.0126	0.0119	0.0097	0.0119
2017	0.0099	0.0118	0.0118	0.0090	0.0120	0.0116	0.0118	0.0118	0.0112	0.0093	0.0112
2018	0.0095	0.0103	0.0103	0.0086	0.0105	0.0102	0.0103	0.0103	0.0098	0.0089	0.0098
2019	NA	0.0097	0.0097	0.0082	0.0099	0.0096	0.0097	0.0097	0.0092	0.0086	0.0092
2020	NA	0.0097	0.0097	0.0077	0.0102	0.0095	0.0097	0.0097	0.0088	0.0083	0.0088
2021	NA	0.0097	0.0097	0.0074	0.0104	0.0094	0.0097	0.0097	0.0084	0.0080	0.0084
2022	NA	0.0097	0.0097	0.0070	0.0107	0.0093	0.0097	0.0097	0.0079	0.0077	0.0079
2023	NA	0.0097	0.0097	0.0066	0.0109	0.0092	0.0097	0.0097	0.0075	0.0074	0.0075
2024	NA	0.0097	0.0097	0.0063	0.0112	0.0091	0.0097	0.0097	0.0071	0.0072	0.0071
2025	NA	0.0097	0.0097	0.0060	0.0114	0.0090	0.0097	0.0097	0.0067	0.0070	0.0067
2026	NA	0.0097	0.0097	0.0057	0.0116	0.0089	0.0097	0.0097	0.0063	0.0067	0.0063
2027	NA	0.0097	0.0097	0.0054	0.0119	0.0088	0.0097	0.0097	0.0059	0.0065	0.0059
2028	NA	0.0097	0.0097	0.0051	0.0121	0.0087	0.0097	0.0097	0.0054	0.0063	0.0054

*1 model failed to converge

AIC COMPARISON GRAPH



LL-Based Comparison Table

Model	Compact LL	Likelihood	AIC*	BIC	HQ	AMSE
M,N,N	69.5168	68.9945	-135.034	-133.488	-134.955	1.8E-05
A,N,N	68.9442	68.4219	-133.888	-132.343	-133.809	1.8E-05
A,M,N	69.7374	69.2151	-131.475	-128.385	-131.317	9.5E-06
M,A,N	69.5856	69.0633	-131.171	-128.081	-131.013	2.0E-05
M,M,N	69.5376	69.0153	-131.075	-127.985	-130.917	1.7E-05
M,AD,N	70.2302	69.7078	-130.460	-126.597	-130.262	2.1E-05
M,MD,N*	70.2061	69.6838	-130.412	-126.549	-130.214	3.1E-05
A,A,N	69.1442	68.6219	-130.288	-127.198	-130.130	1.7E-05
A,MD,N	69.7899	69.2676	-129.580	-125.717	-129.382	9.3E-06
A,AD,N	69.1442	68.6219	-128.288	-124.425	-128.090	NA

*1 model failed to converge

APPENDIX E: FORECAST OF COAL HOURS

As described in Appendices A-D, MSHA forecasted incident rates that require hours to translate back to the number of fatalities and injuries. MSHA used the following steps to estimate employee hours in the future. The Energy Information Administration (EIA) issues periodic forecasts for U.S. coal supply, both short term and long term. The supply total is composed of production, inventory, waste, imports, and exports. Additionally, there are very small differences between the MSHA coal production totals and the EIA data over the period 2003-2018. The relationship is reasonable to use the EIA year over year forecast as an input to MSHA's forecast for this proposed rule. MSHA used the following steps below to forecast hours starting with the EIA forecast and MSHA data for hours and production. The resulting data both historical and forecast are shown in the table below.

1. Calculate the year over year change for the EIA coal production forecast. (EIA AEO2019 forecast Coal Production: United States Total: Reference case, API Key 95-AEO2019.71.ref2019-d111618a; https://www.eia.gov/outlooks/aeo/data/browser/#/?id=95-AEO2019&cases=ref2019&sid=ref2019-d111618a.71-95-AEO2019&sourcekey=0)
2. Apply the EIA year over year growth to the MSHA production values from 2018 forward to estimate production for 2019-2030.
3. Calculate the tons per hour as a productivity measure for the years 2003-2018.
4. The productivity (production/hour) dropped from 2008 to 2012 and then returned to previous historic levels. Coal mining as an industry has had substantial consolidations and closures. Because the ratio has not been constant, MSHA determined that using a 5-year moving average (sum of production/sum of hours) is a satisfactorily representative value.
5. Divide the annual production for 2019-2030 by the corresponding tons/hour value.

Coal Production, Productivity and Hours

Calendar Year	EIA Production (tons)	EIA Production Change	MSHA Coal Production (tons)	Coal Hours	MSHA Production TONS//HR
2003	1,071,752,573		1,070,293,598	150,818,604	7.09656
2004	1,112,098,870	1.03765	1,110,876,721	159,921,424	6.94639
2005	1,131,498,099	1.01744	1,133,226,812	174,362,615	6.49925
2006	1,162,749,659	1.02762	1,162,538,522	181,859,979	6.39249
2007	1,146,635,345	0.98614	1,146,375,530	179,120,116	6.40004
2008	1,171,808,669	1.02195	1,172,399,003	192,697,482	6.08414
2009	1,074,923,392	0.91732	1,074,673,869	187,653,879	5.72689
2010	1,084,368,148	1.00879	1,086,271,338	191,627,899	5.66865
2011	1,095,627,536	1.01038	1,094,926,452	208,029,731	5.26332
2012	1,016,458,418	0.92774	1,017,739,138	193,063,045	5.27154
2013	984,841,779	0.96890	983,978,894	175,828,115	5.59625
2014	1,000,048,758	1.01544	1,000,050,560	166,106,385	6.02054
2015	896,940,563	0.89690	896,748,688	141,054,637	6.35746
2016	728,364,498	0.81205	728,311,940	108,629,068	6.70458
2017	768,702,942	1.05538	774,680,308	117,094,906	6.61583
2018	762,238,464	0.99159	755,965,000	120,276,227	6.28524
2019	735,517,517	0.96494	729,460,867	114,649,497	6.36253
2020	693,630,615	0.94305	687,918,071	106,539,331	6.45694
2021	662,171,692	0.95465	656,720,986	101,319,563	6.48168
2022	653,978,088	0.98763	648,597,347	100,738,433	6.43843
2023	649,121,033	0.99257	643,778,269	100,587,054	6.40021
2024	657,351,746	1.01268	651,941,377	101,444,055	6.42661
2025	654,049,072	0.99498	648,668,631	100,709,305	6.44100
2026	649,431,274	0.99294	644,089,030	100,050,644	6.43763
2027	642,447,327	0.98925	637,165,073	99,111,505	6.42877
2028	632,653,320	0.98476	627,454,677	97,630,508	6.42683
2029	647,316,956	1.02318	641,999,076	99,810,186	6.43220
2030	647,072,998	0.99962	641,755,116	99,754,578	6.43334

APPENDIX F: METAL NON METAL HOURS FORECASTING

As described in Appendices A-D, MSHA forecasted incident rates that requires hours to translate back to the number of fatalities and injuries. MSHA developed a forecast of non-administrative hours for MNM by developing a regression equation that used economic inputs related to the future growth of the economy in general and various investment variables used for the U.S. macro economy reporting. MSHA used the Congressional Budget Office (CBO) August 2019 Long Term Outlook as a source for the future independent variables. MSHA does not assert that this is the single best model, but rather that the model presented is a reasonable approach to estimating future changes in hour usage for the metal nonmetal mining sector in total. The forecast hours reflect the slower long term real growth of the economy in the CBO forecast. The consideration for inputs, the regression diagnostics, and resulting modeled hours follow.

Considerations For Independent Economic Variables

1. The forecast source preferably should be publicly available and from a nationally recognized organization. The CBO provides their forecasts with the assumptions and data in a time series format. MSHA used the CBO August 2019 calendar year long term forecast. The selected variables were extended one period by using a 5-year linear trend (Excel: “Forecast.Linear”.)
2. The variables to be considered must reflect a measure of the future national macro economy.
3. Although the overall economy and macroeconomic investment in general are likely candidate variables, the relationship may be to either real or nominal values. MSHA included the GDP price index in the starting list as possible inputs with the mix of real and nominal values.
4. The economic variables may have a relationship to the hours in the same year or there might be a lagged effect. To allow for the possibility of a lag, MSHA included one period lags in the specification for the regression. The lagged variables include a (-1) after the name in the modeling output.
5. The variable names from the CBO data were modified only when variable name length was too long. This resulted in truncating longer names to 24 characters, the EViews maximum length.
6. MSHA estimated the equation using the EViews stepwise regression procedure (STEPLS) maximum R-squared contribution. The stepwise estimates were further refined by manually removing variables with $p>0.05$.

Variable Names and Description

VARIABLE AS USED (CBO Variable Truncated)	CBO VARIABLE	SHORT DEFINITION
DATE	Calendar Year	Calendar Year
MNM_EH	n/a	Metal Nonmetal miner hours
GDP	GDP	The value of the goods and services produced in the U.S.
REAL_GDP	real_gdp	Market value of U.S. production, inflation adjusted.
REAL_GNP	real_gnp	Market value of all goods and services produced, inflation adjusted.
GDP_PRICE_INDEX	GDP_PRICE_INDEX	A measure of inflation of goods and services produced in the U.S.
CORP_PROFITS_DOMESTIC_AD	corp_profits_domestic_adj	Corporate domestic profits, adjusted for inventory valuation & capital consumption.
PCE	pce	The value of goods & services purchased by persons.
REAL_GROSS_PRI_DOM_INVES	gross_pri_dom_invest	Private fixed investment and change in private inventories
NONRES_FIXED_INVEST	nonres_fixed_invest	Purchases of both nonresidential structures, equipment, and software.
GOVERNMENT_C_GI	government_c_gi	Government purchases of inputs to labor, intermediate goods, services, investment.
FEDERAL_GOVERNMENT_C_GI	federal_government_c_gi	Federal expenditures plus social benefits, transfers, interest payments, and subsidies
GROSS_PRI_DOM_INVEST	gross_pri_dom_invest	Private fixed investment and change in private inventories.
REAL_NONRES_FIXED_INVEST	real_nonres_fixed_invest	Private fixed investment and change in private inventories, inflation adjusted.
REAL_CHANGE_PRI_INVEST	real_change_pri_invest	
REAL_GOVERNMENT_C_GI	real_government_c_gi	Market value of all goods and services produced, inflation adjusted.

REAL_FEDL_GOVT_C_GI	real_federal_government_c_gi	Federal government cost of goods and services, inflation adjusted.
REAL_SL_GOVERNMENT_C_GI	real_sl_government_c_gi	Government spending on goods & services, inflation adjusted

Hours and Economic Variables Used For MNM Hours Forecast

OBS	MNM_EH	CORP_PROFITS_DOMESTIC_AD	FEDERAL_GOVERNMENT_C_GI	GDP	GDP_PRICE_INDEX	GOVERNMENT_C_GI	GROSS_PRI_DOM_INVEST	NONRES_FIXED_INVEST
2003	292,968,066	897.3500	826.2750	11,458.2500	82.5670	2,211.2000	2,027.0500	1,375.8750
2004	301,582,837	1,094.2000	891.7500	12,213.7250	84.7783	2,338.9000	2,281.2750	1,467.3750
2005	311,291,592	1,262.9000	947.4750	13,036.6250	87.4070	2,476.0000	2,534.7500	1,620.9750
2006	318,850,638	1,406.5250	1,000.6750	13,814.6000	90.0740	2,624.2500	2,700.9500	1,793.7750
2007	317,572,444	1,195.4000	1,050.5250	14,451.8750	92.4978	2,790.8500	2,673.0250	1,948.5500
2008	301,729,081	895.6500	1,150.6000	14,712.8250	94.2635	2,981.9750	2,477.6000	1,990.8500
2009	248,862,511	1,038.0250	1,218.1750	14,448.9250	94.9990	3,073.5250	1,929.6750	1,690.4250
2010	255,116,558	1,342.9500	1,297.9250	14,992.0500	96.1088	3,154.6500	2,165.4750	1,735.0000
2011	267,072,680	1,397.2000	1,298.9250	15,542.6000	98.1115	3,148.3750	2,332.5750	1,907.4750
2012	276,002,979	1,592.0500	1,286.5500	16,197.0500	100.0000	3,137.0000	2,621.7750	2,118.5500
2013	279,726,182	1,611.8500	1,226.5750	16,784.8250	101.7725	3,132.4000	2,826.0000	2,211.4750
2014	286,071,314	1,713.9500	1,214.1750	17,521.7500	103.6875	3,167.0250	3,038.9250	2,394.3250
2015	285,491,004	1,654.7250	1,220.8750	18,219.3000	104.7573	3,234.2250	3,211.9500	2,449.7000
2016	278,927,854	1,628.4750	1,232.2250	18,707.1500	105.8985	3,290.9500	3,169.9000	2,442.1250

2017	283,946,573	1,650.4500	1,265.2000	19,485.4000	107.9318	3,374.4500	3,367.9500	2,587.8750
2018	294,790,231	1,778.3750	1,319.8000	20,494.0500	110.3308	3,520.8250	3,650.0750	2,799.0500
2019		1,798.0970	1,382.0090	21,360.1325	112.1665	3,670.8140	3,802.2005	2,925.9135
2020		1,895.4653	1,445.4173	22,230.9500	114.3170	3,816.1975	3,946.6048	3,046.4365
2021		1,954.5630	1,478.5460	23,082.7400	116.5754	3,928.9773	4,105.3503	3,148.6468
2022		1,992.0655	1,511.5860	23,945.5450	118.8940	4,047.2343	4,229.3295	3,224.9760
2023		2,048.8278	1,547.9018	24,835.9825	121.2796	4,175.8533	4,343.9813	3,297.9483
2024		2,107.9625	1,585.4003	25,768.9750	123.7529	4,310.8160	4,479.4775	3,391.5488
2025		2,190.0443	1,623.8525	26,765.2500	126.2907	4,449.9283	4,632.1173	3,502.9575
2026		2,256.6710	1,663.1550	27,775.4425	128.8778	4,592.4898	4,803.3648	3,630.6618
2027		2,346.1485	1,703.5148	28,860.1150	131.5126	4,737.6723	4,991.6268	3,765.5888
2028		2,439.5115	1,747.2348	29,981.4225	134.1913	4,888.6755	5,181.8360	3,917.1280
2029		2,524.6870	1,793.9363	31,141.2500	136.9072	5,045.0188	5,372.3068	4,072.2400
2030		2,607.0503	1,833.6128	32,192.0900	139.5198	5,188.6669	5,553.9054	4,205.2246

Hours and Economic Variables Used for MNM Hours Forecast (continued)

OBS	PCE	REAL_CHANGE_PRI_INVEST	REAL_FEDERAL_GOVERNMENT	REAL_GDP	REAL_GNP	REAL_GOVERNMENT_C_GI	REAL_GROSS_PRI_DOM_INVES	REAL_NONRES_FIXED_INVEST	REAL_SL_GOVERNMENT_C_GI

2003	7723.1250	19.9250	1,032.7500	13,879.1250	13,953.9500	2,947.1750	2,290.3750	1,509.3500	1,922.2000
2004	8212.6500	82.6500	1,077.4750	14,406.3750	14,503.0250	2,992.7250	2,502.5500	1,594.0000	1,920.0750
2005	8747.1250	63.7250	1,099.1000	14,912.5250	15,006.0500	3,015.4750	2,670.5750	1,716.3500	1,920.0500
2006	9260.3500	87.1000	1,125.0250	15,338.2500	15,398.6500	3,063.5000	2,752.4250	1,854.1500	1,941.6000
2007	9706.4250	40.5750	1,146.9750	15,626.0250	15,748.3000	3,118.5750	2,684.1500	1,982.0500	1,974.6750
2008	9976.3500	-32.6750	1,218.7750	15,604.6750	15,771.5750	3,195.5500	2,462.9000	1,994.2250	1,978.6250
2009	9842.2000	-177.3000	1,293.0250	15,208.8250	15,359.3500	3,307.3250	1,941.9500	1,704.3250	2,015.5750
2010	10185.8500	57.3000	1,346.0750	15,598.7500	15,803.8500	3,307.2250	2,216.5000	1,781.0000	1,961.2750
2011	10641.1250	46.7000	1,311.1000	15,840.6750	16,081.6500	3,203.3250	2,362.1250	1,935.3500	1,892.2000
2012	11006.8000	71.2250	1,286.5250	16,197.0000	16,429.3250	3,137.0000	2,621.7750	2,118.5500	1,850.5000
2013	11317.2000	108.6500	1,215.2500	16,495.3750	16,722.3250	3,061.0500	2,801.4750	2,205.9500	1,845.3250
2014	11824.0250	86.6250	1,183.2000	16,899.8250	17,135.0750	3,032.2750	2,951.5750	2,357.3750	1,848.1000
2015	12294.5250	129.0250	1,183.0250	17,386.6750	17,608.2750	3,088.5250	3,092.2250	2,399.7500	1,903.9000
2016	12766.9000	23.3750	1,187.8250	17,659.2000	17,867.8000	3,132.5000	3,050.5000	2,411.2250	1,942.8000
2017	13321.4000	22.5000	1,196.3750	18,050.7000	18,284.0250	3,130.4000	3,196.6250	2,538.0750	1,932.3500
2018	13948.5250	45.0250	1,227.4750	18,566.4750	18,815.8750	3,176.1750	3,385.3000	2,713.6000	1,947.6000
2019	14519.6825	74.3576	1,262.2973	19,043.3500	19,287.6575	3,250.1510	3,483.7775	2,798.0953	1,986.9793
2020	15156.2025	42.4417	1,299.6768	19,446.2075	19,693.8975	3,305.1650	3,572.5680	2,885.0763	2,005.4030
2021	15758.3400	38.2466	1,304.6710	19,800.1825	20,048.6775	3,324.3563	3,669.4918	2,954.6500	2,019.4233
2022	16403.7275	36.3603	1,308.1228	20,139.7250	20,390.7125	3,342.5500	3,734.5173	3,001.0025	2,033.9033
2023	17078.1250	37.3087	1,313.1013	20,477.7675	20,736.4725	3,362.1368	3,788.2468	3,044.1793	2,048.2945
2024	17768.6225	39.8685	1,318.2910	20,822.3550	21,092.2300	3,381.0890	3,854.2755	3,103.6488	2,061.8578
2025	18504.5375	43.8311	1,323.5688	21,192.7950	21,472.8025	3,399.0850	3,930.8093	3,177.4108	2,074.3988
2026	19229.9675	39.8757	1,328.9160	21,551.1825	21,839.3500	3,416.5348	4,018.7483	3,263.6780	2,086.3378
2027	20021.2550	44.0770	1,334.6175	21,944.1025	22,241.4300	3,434.1068	4,116.0505	3,353.8415	2,098.0663
2028	20842.3550	46.5493	1,342.3523	22,341.6825	22,647.7000	3,453.7283	4,212.2590	3,456.6928	2,109.9508
2029	21696.0575	47.5208	1,351.5800	22,745.6150	23,058.8075	3,474.8303	4,307.3563	3,561.0875	2,121.9388
2030	22457.4628	48.5867	1,357.0445	23,123.9175	23,446.1260	3,492.2622	4,401.0261	3,650.6526	2,133.7464

Source: CBO Aug. 2019 long-term forecast; https://www.cbo.gov/data/budget-economic-data#11; Variables extended one year using a five year linear trend.

Stepwise Regression Diagnostics and Model Results

Dependent Variable: MNM_EH
Method: Stepwise Regression
Sample (adjusted): 2004 2018
Included observations: 15 after adjustments
Number of always included regressors: 1
Number of search regressors: 29
Selection method: Stepwise forwards
Stopping criterion: p-value forwards/backwards = 0.5/0.5

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
C	2.08E+08	1417020.	146.5683	0.0043
REAL_GOVERNMENT_C_GI(-1)	-1121866.	4213.542	-266.2523	0.0024
NONRES_FIXED_INVEST	60659.14	39.06973	1552.587	0.0004
CORP_PROFITS_DOMESTIC_AD(-1)	29832.48	44.10475	676.4007	0.0009
GOVERNMENT_C_GI(-1)	-134001.4	753.9774	-177.7260	0.0036
GROSS_PRI_DOM_INVEST(-1)	31846.93	41.32625	770.6222	0.0008
FEDERAL_GOVERNMENT_C_GI	164144.1	406.1152	404.1811	0.0016
REAL_FEDERAL_GOVERNMENT_(-1)	1190261.	4394.148	270.8740	0.0024
REAL_NONRES_FIXED_INVEST(-1)	-27249.13	155.8450	-174.8476	0.0036
REAL_GNP	-23308.41	41.59145	-560.4135	0.0011
REAL_GROSS_PRI_DOM_INVES	37712.81	150.0643	251.3110	0.0025
REAL_SL_GOVERNMENT_C_GI(-1)	1216838.	4178.285	291.2290	0.0022
GDP_PRICE_INDEX(-1)	833450.4	21600.24	38.58524	0.0165
REAL_GNP(-1)	1257.721	64.41780	19.52443	0.0326

R-squared	1.000000	Mean dependent var	2.87E+08
Adjusted R-squared	1.000000	S.D. dependent var	20957135
S.E. of regression	3191.580	Akaike info criterion	18.13304
Sum squared resid	10186183	Schwarz criterion	18.79388

Log likelihood	-121.9978	Hannan-Quinn criter.	18.12600
F-statistic	46434099	Durbin-Watson stat	2.777105
Prob(F-statistic)	0.000115		

Selection Summary

Added REAL_GOVERNMENT_C_GI(-1)
Added FEDERAL_GOVERNMENT_C_GI(-1)
Added CORP_PROFITS_DOMESTIC_AD(-1)
Added GOVERNMENT_C_GI(-1)
Added NONRES_FIXED_INVEST
Removed FEDERAL_GOVERNMENT_C_GI(-1)
Added REAL_NONRES_FIXED_INVEST
Added FEDERAL_GOVERNMENT_C_GI
Added REAL_GROSS_PRI_DOM_INVES(-1)
Removed REAL_NONRES_FIXED_INVEST
Added REAL_FEDERAL_GOVERNMENT_(-1)
Added GROSS_PRI_DOM_INVEST(-1)
Removed REAL_GROSS_PRI_DOM_INVES(-1)
Added REAL_NONRES_FIXED_INVEST(-1)
Added REAL_GNP
Added REAL_GROSS_PRI_DOM_INVES
Added REAL_SL_GOVERNMENT_C_GI(-1)
Added GDP_PRICE_INDEX(-1)
Added REAL_GNP(-1)

*Note: p-values and subsequent tests do not account for stepwise selection.

Estimation Command:

STEPLS(FMAXSTEP=5000,BMAXSTEP=5000,TMAXSTEP=10000) MNM_EH C @
CORP_PROFITS_DOMESTIC_AD FEDERAL_GOVERNMENT_C_GI
GDP
GDP_PRICE_INDEX
GOVERNMENT_C_GI
GROSS_PRI_DOM_INVEST
NONRES_FIXED_INVEST
PCE
REAL_GDP
REAL_GNP
REAL_GOVERNMENT_C_GI
REAL_GROSS_PRI_DOM_INVES
REAL_NONRES_FIXED_INVEST

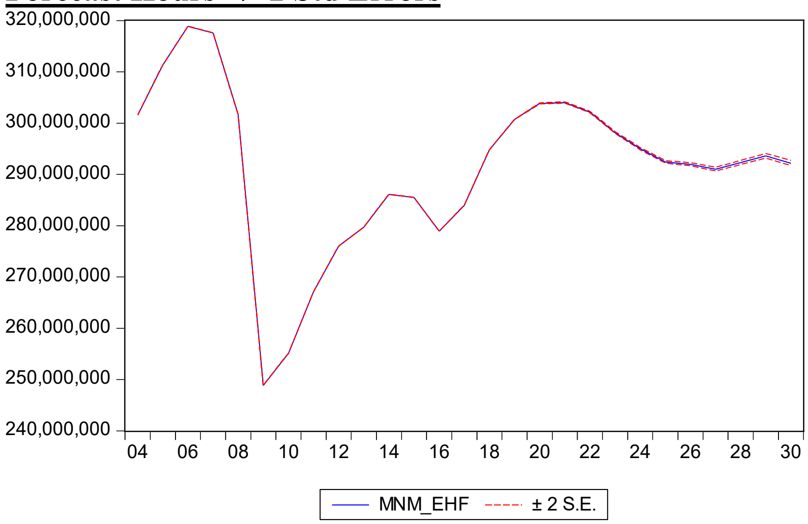
REAL_SL_GOVERNMENT_C_GI CORP_PROFITS_DOMESTIC_AD(-1)
FEDERAL_GOVERNMENT_C_GI(-1)
GDP(-1)
GDP_PRICE_INDEX(-1)
GOVERNMENT_C_GI(-1)
GROSS_PRI_DOM_INVEST(-1)
PCE(-1)
REAL_CHANGE_PRI_INVEST(-1)
REAL_FEDERAL_GOVERNMENT_(-1)
REAL_GDP(-1)
REAL_GNP(-1)
REAL_GOVERNMENT_C_GI(-1)
REAL_GROSS_PRI_DOM_INVES(-1)
REAL_NONRES_FIXED_INVEST(-1)
REAL_SL_GOVERNMENT_C_GI(-1)

Estimation Equation:
MNM_EH = C(1) + C(2)*REAL_GOVERNMENT_C_GI(-1) +
C(3)*NONRES_FIXED_INVEST + C(4)*CORP_PROFITS_DOMESTIC_AD(-1) +
C(5)*GOVERNMENT_C_GI(-1) + C(6)*GROSS_PRI_DOM_INVEST(-1) +
C(7)*FEDERAL_GOVERNMENT_C_GI + C(8)*REAL_FEDERAL_GOVERNMENT_(-1) +
C(9)*REAL_NONRES_FIXED_INVEST(-1) + C(10)*REAL_GNP +
C(11)*REAL_GROSS_PRI_DOM_INVES + C(12)*REAL_SL_GOVERNMENT_C_GI(-1) +
C(13)*GDP_PRICE_INDEX(-1) + C(14)*REAL_GNP(-1)

Substituted Coefficients:

MNM_EH = 207690244.165 - 1121865.53506*REAL_GOVERNMENT_C_GI(-1) + 60659.143384*NONRES_FIXED_INVEST + 29832.4802728*CORP_PROFITS_DOMESTIC_AD(-1) - 134001.359878*GOVERNMENT_C_GI(-1) + 31846.9272737*GROSS_PRI_DOM_INVEST(-1) + 164144.10686*FEDERAL_GOVERNMENT_C_GI + 1190260.61534*REAL_FEDERAL_GOVERNMENT_(-1) - 27249.1291592*REAL_NONRES_FIXED_INVEST(-1) - 23308.406047*REAL_GNP + 37712.8084771*REAL_GROSS_PRI_DOM_INVES + 1216837.692*REAL_SL_GOVERNMENT_C_GI(-1) + 833450.371565*GDP_PRICE_INDEX(-1) + 1257.72099209*REAL_GNP(-1)

Forecast Hours +/- 2 Std Errors

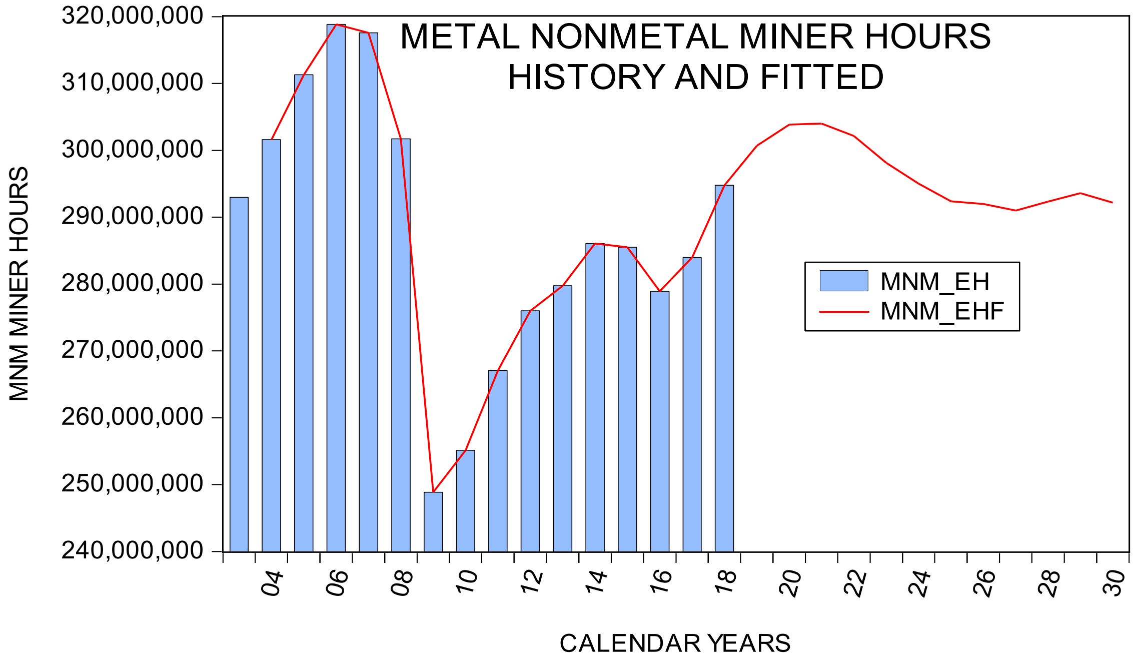


Forecast: MNM_EHF	
Actual: MNM_EH	
Forecast sample: 2003 2030	
Adjusted sample: 2004 2030	
Included observations: 15	
Root Mean Squared Error	824.0624
Mean Absolute Error	635.4917
Mean Abs. Percent Error	0.000222
Theil Inequality Coefficient	1.43E-06
Bias Proportion	0.000000
Variance Proportion	0.000000
Covariance Proportion	1.000000

Metal Nonmetal Historical and Fitted Hours Data

YEAR	HISTORICAL HOURS (MNM_EH)	FORECAST, FITTED (MNM_EHF)
2003	292,968,066	301,583,142
2004	301,582,837	311,290,698
2005	311,291,592	318,850,721
2006	318,850,638	317,573,575
2007	317,572,444	301,728,438
2008	301,729,081	248,862,594
2009	248,862,511	255,116,824
2010	255,116,558	267,071,198
2011	267,072,680	276,004,901
2012	276,002,979	279,726,147
2013	279,726,182	286,070,417
2014	286,071,314	285,490,593
2015	285,491,004	278,928,415
2016	278,927,854	283,946,989
2017	283,946,573	294,789,827
2018	294,790,231	301,583,142
2019	NA	300,706,497
2020	NA	303,834,995
2021	NA	304,005,648
2022	NA	302,152,469
2023	NA	298,144,535
2024	NA	294,995,421
2025	NA	292,382,836
2026	NA	291,958,888
2027	NA	290,986,611
2028	NA	292,313,602
2029	NA	293,596,711
2030	NA	292,170,821

Metal Nonmetal Historical and Fitted Hours Plot



NOTES: Metal Nonmetal Fitted (MNM_EHF) plotted with Historical Hours (MNM_EH)
Axes: Horizontal: Years 2003-2030; Vertical: Hours

Average Annual Metal Nonmetal Hours: Historical, All Periods, and Forecast.

MEAN, HISTORICAL	287,500,159
MEAN, ALL PERIOD	291,330,414
MEAN, FORECAST	296,437,420

APPENDIX G: RATES, HOURS AND INCIDENTS

Appendix G Methodology and Notes

As described in Appendices A-D, MSHA forecasted incident rates. To convert incident rates back to the number of fatalities and injuries, MSHA transformed the equation for incident rates to solve for hours given incident rates. As shown in Appendix A, the formula for incident rates is:

$$IR = (\textit{Number of Injury Occurrences} \div \textit{Number of Employee Hours}) \times 200{,}000.$$

The transformed equation to convert back to the number of injury occurrences is:

$$\textit{Number of Injury Occurrences} = (IR\ X\ \textit{Number of employee hours})/200{,}000.$$

The tables that follow present the outputs of the models developed in Appendices B-F. As mentioned in the estimation of the Coal Fatality Incident rate, it is possible to have no fatalities or incidents in a year, such as no fatalities in 2016 and 2018. However, MSHA does not believe that a baseline trend can eliminate fatalities without the proposal. When transforming the incident rates back to incidents, MSHA placed a floor of at least one fatality per year and requests comment on whether this floor is appropriate or whether another methodology would be more appropriate. The proposed rule benefit analysis reduces the baseline by eighty percent and the benefit dollars use the resulting decimal. The following tables show both the history and the forecast for hours, incident rates, and the number of incidents for fatalities and injuries.

Coal Incident Rates, Hours, Fatalities, and Injuries: History and Forecast Periods

		HISTORICAL AND FORECAST RATES			HISTORICAL AND FORECAST INCIDENTS			ROUNDED HISTORICAL AND FORECAST INCIDENTS		
YEAR	HOURS	FATALITIES f_ir_consol	NON-FATAL DAYS LOST INCIDENT RATE	NO DAYS LOST INCIDENT RATE	FATALITIES f_ir_consol	NON-FATAL DAYS LOST INCIDENTS nfdl_ir_consol	NO DAYS LOST INCIDENTS ndl_ir_consol	FATALITIES	NON-FATAL DAYS LOST INCIDENTS	NO DAYS LOST INCIDENTS
2003	148,642,245	0.008	0.032	0.009	6	24	7	6	24	7
2004	159,281,269	0.005	0.044	0.019	4	35	15	4	35	15
2005	175,415,838	0.006	0.038	0.029	5	33	25	5	33	25
2006	183,052,022	0.002	0.046	0.014	2	42	13	2	42	13
2007	180,288,410	0.004	0.036	0.013	4	32	12	4	32	12
2008	193,302,274	0.004	0.031	0.018	4	30	17	4	30	17
2009	187,951,981	0.005	0.038	0.016	5	36	15	5	36	15
2010	191,424,545	0.003	0.031	0.010	3	30	10	3	30	10
2011	204,219,032	0.002	0.035	0.010	2	36	10	2	36	10
2012	191,805,457	0.002	0.020	0.007	2	19	7	2	19	7
2013	177,321,835	0.001	0.018	0.006	1	16	5	1	16	5

2014	167,895,285	0.004	0.018	0.018	3	15	15	3	15	15
2015	142,092,626	0.003	0.023	0.007	2	16	5	2	16	5
2016	105,722,518	0.000	0.020	0.004	0	11	2	0	11	2
2017	115,542,611	0.007	0.031	0.009	4	18	5	4	18	5
2018	121,910,145	0.000	0.033	0.010	0	20	6	0	20	6
2019	119,524,910	0.002	0.031	0.007	0.896	19.225	3.815	1	19	4
2020	106,894,778	0.001	0.031	0.007	0.748	16.777	3.589	1	17	4
2021	101,522,647	0.001	0.031	0.006	0.650	15.934	3.209	1	16	3
2022	101,659,879	0.001	0.031	0.006	0.596	15.955	3.026	1	16	3
2023	102,102,861	0.001	0.031	0.006	0.548	16.025	2.862	1	16	3
2024	102,970,772	0.001	0.031	0.005	0.506	16.161	2.717	1	16	3
2025	101,589,938	0.001	0.031	0.005	0.458	15.944	2.524	1	16	3
2026	101,045,260	0.001	0.031	0.005	0.417	15.859	2.364	1	16	2
2027	100,255,472	0.001	0.031	0.004	0.379	15.735	2.209	1	16	2
2028	98,802,575	0.001	0.031	0.004	0.342	15.507	2.049	1	16	2
2029	100,953,215	0.001	0.031	0.004	0.320	15.844	1.972	1	16	2

2030	100,825,653	0.001	0.031	0.004	1.008	13.207	1.396	1	13	1

Forecast Override Note: Individual years may result in zeros incidents however MSHA could not identify periods of sustained values of zero incidents. For this reason, MSHA set a floor of one fatality when rounding.

Metal Nonmetal Incident Rates, Hours, Fatalities, and Injuries: History and Forecast Periods

		HISTORICAL AND FORECAST INCIDENT RATES			HISTORICAL AND FORECAST INCIDENTS			ROUNDED HISTORICAL AND FORECAST INCIDENTS		
YEAR	HOURS HISTORICAL AND FORECAST	FATALITIES f_ir_consol (See Override note)	NON-FATAL DAYS LOST INCIDENT RATE	NO DAYS LOST INCIDENT RATE	FATALITIES f_ir_consol	NON-FATAL DAYS LOST INCIDENTS nfdl_ir_consol	NO DAYS LOST INCIDENTS ndl_ir_consol	FATALITIES	NON-FATAL DAYS LOST INCIDENTS	NO DAYS LOST INCIDENTS
2003	292,968,066	0.0007	0.0314	0.0143	1	46	21	1	46	21
2004	301,582,837	0.0013	0.0391	0.0192	2	59	29	2	59	29
2005	311,291,592	0.0039	0.0353	0.0161	6	55	25	6	55	25
2006	318,850,638	0.0031	0.0389	0.0238	5	62	38	5	62	38
2007	317,572,444	0.0025	0.0277	0.0170	4	44	27	4	44	27
2008	301,729,081	0.0013	0.0464	0.0152	2	70	23	2	70	23
2009	248,862,511	0.0032	0.0241	0.0121	4	30	15	4	30	15
2010	255,116,558	0.0024	0.0361	0.0102	3	46	13	3	46	13
2011	267,072,680	0.0007	0.0195	0.0090	1	26	12	1	26	12

2012	276,002,979	0.0029	0.0261	0.0058	4	36	8	4	36	8
2013	279,726,182	0.0029	0.0243	0.0093	4	34	13	4	34	13
2014	286,071,314	0.0042	0.0266	0.0112	6	38	16	6	38	16
2015	285,491,004	0.0021	0.0182	0.0133	3	26	19	3	26	19
2016	278,927,854	0.0036	0.0208	0.0115	5	29	16	5	29	16
2017	283,946,573	0.0042	0.0197	0.0099	6	28	14	6	28	14
2018	294,790,231	0.0041	0.0197	0.0095	6	29	14	6	29	14
2019	300,706,497	0.0032	0.0164	0.0097	4.84	24.66	14.58	5	25	15
2020	303,834,995	0.0033	0.0150	0.0097	4.97	22.77	14.74	5	23	15
2021	304,005,648	0.0033	0.0136	0.0097	4.96	20.63	14.74	5	21	15
2022	302,152,469	0.0033	0.0122	0.0097	4.91	18.36	14.65	5	18	15
2023	298,144,535	0.0033	0.0107	0.0097	4.86	16.00	14.46	5	16	14
2024	294,995,421	0.0033	0.0093	0.0097	4.81	13.74	14.31	5	14	14
2025	292,382,836	0.0033	0.0079	0.0097	4.76	11.55	14.18	5	12	14
2026	291,958,888	0.0033	0.0065	0.0097	4.76	9.46	14.16	5	9	14
2027	290,986,611	0.0033	0.0051	0.0097	4.74	7.37	14.11	5	7	14

2028	292,313,602	0.0033	0.0036	0.0097	4.76	5.33	14.18	5	5	14
2029	293,596,711	0.0033	0.0022	0.0097	4.78	3.28	14.24	5	3	14
2030	292,170,821	0.0033	0.0008	0.0097	4.76	1.19	14.17	5	1	14

Note Fatality Incident Rate Forecast Override: MSHA examined all of the fatality incident rate models for metal nonmetal. Although MSHA found that the wide range of historical values created some trend models with good AIC and mean squared error test values for the in sample fit, the out of sample forecasts were questionable. Additionally, the methodology could not converge on a solution for a number of the parameter choices. The forecast comparison graphs in Appendix D show all of the ETS fitted forecasts. MSHA experimented with outlier substitution and alternate in-sample periods. Both of these approaches resulted in models that remained highly dependent on the noticeable historical incident rate increase in the years 2010-2018. The recession of 2008-2009[34] may have created additional changes in mining safety not represented by time series modeling. MSHA chose a three-year moving average to dampen the highs and lows and extended the moving average of the dampened series throughout the forecast periods. The table above shows the historical values for 2003-2018 and the forecast override values for the ten forecast years. MSHA finds the results of the simple forecast superior to the more complicated trend methodologies

[34] See US Business Cycle Expansions and Contractions | NBER for official dating of business cycles in the U.S.