project_4_starter

November 5, 2018

1 Project 4: Multi-factor Model

1.1 Instructions

Each problem consists of a function to implement and instructions on how to implement the function. The parts of the function that need to be implemented are marked with a `# TODO` comment. After implementing the function, run the cell to test it against the unit tests we've provided. For each problem, we provide one or more unit tests from our `project_tests` package. These unit tests won't tell you if your answer is correct, but will warn you of any major errors. Your code will be checked for the correct solution when you submit it to Udacity.

1.2 Packages

When you implement the functions, you'll only need to you use the packages you've used in the classroom, like Pandas and Numpy. These packages will be imported for you. We recommend you don't add any import statements, otherwise the grader might not be able to run your code.

The other packages that we're importing are `project_helper` and `project_tests`. These are custom packages built to help you solve the problems. The `project_helper` module contains utility functions and graph functions. The `project_tests` contains the unit tests for all the problems.

1.2.1 Install Packages

```
In [1]: import sys
        !{sys.executable} -m pip install -r requirements.txt
```

```
Requirement already satisfied: alphalens==0.3.2 in /opt/conda/lib/python3.6/site-packages (from
Requirement already satisfied: colour==0.1.5 in /opt/conda/lib/python3.6/site-packages (from -r
Requirement already satisfied: cvxpy==1.0.3 in /opt/conda/lib/python3.6/site-packages (from -r r
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Requirement already satisfied: pandas==0.18.1 in /opt/conda/lib/python3.6/site-packages (from -r
Requirement already satisfied: plotly==2.2.3 in /opt/conda/lib/python3.6/site-packages (from -r
Requirement already satisfied: pyparsing==2.2.0 in /opt/conda/lib/python3.6/site-packages (from
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Requirement already satisfied: six==1.11.0 in /opt/conda/lib/python3.6/site-packages (from -r re
Requirement already satisfied: tqdm==4.19.5 in /opt/conda/lib/python3.6/site-packages (from -r r
Requirement already satisfied: zipline===1.2.0 in /opt/conda/lib/python3.6/site-packages (from -
Requirement already satisfied: matplotlib>=1.4.0 in /opt/conda/lib/python3.6/site-packages (from
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Requirement already satisfied: toolz in /opt/conda/lib/python3.6/site-packages (from cvxpy==1.0.
Requirement already satisfied: fastcache in /opt/conda/lib/python3.6/site-packages (from cvxpy==
Requirement already satisfied: multiprocess in /opt/conda/lib/python3.6/site-packages (from cvxp
Requirement already satisfied: nbformat>=4.2 in /opt/conda/lib/python3.6/site-packages (from plo
Requirement already satisfied: decorator>=4.0.6 in /opt/conda/lib/python3.6/site-packages (from
Requirement already satisfied: chardet<3.1.0,>=3.0.2 in /opt/conda/lib/python3.6/site-packages (
Requirement already satisfied: idna<2.7,>=2.5 in /opt/conda/lib/python3.6/site-packages (from re
Requirement already satisfied: urllib3<1.23,>=1.21.1 in /opt/conda/lib/python3.6/site-packages (
Requirement already satisfied: certifi>=2017.4.17 in /opt/conda/lib/python3.6/site-packages (fro
Requirement already satisfied: multipledispatch>=0.4.8 in /opt/conda/lib/python3.6/site-packages
Requirement already satisfied: sortedcontainers>=1.4.4 in /opt/conda/lib/python3.6/site-packages
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Requirement already satisfied: contextlib2>=0.4.0 in /opt/conda/lib/python3.6/site-packages (fro
Requirement already satisfied: requests-file>=1.4.1 in /opt/conda/lib/python3.6/site-packages (f
Requirement already satisfied: bottleneck>=1.0.0 in /opt/conda/lib/python3.6/site-packages (from
Requirement already satisfied: Logbook>=0.12.5 in /opt/conda/lib/python3.6/site-packages (from z
Requirement already satisfied: setuptools>18.0 in /opt/conda/lib/python3.6/site-packages (from z
Requirement already satisfied: intervaltree>=2.1.0 in /opt/conda/lib/python3.6/site-packages (fr
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Requirement already satisfied: numexpr>=2.6.1 in /opt/conda/lib/python3.6/site-packages (from zi
Requirement already satisfied: Mako>=1.0.1 in /opt/conda/lib/python3.6/site-packages/Mako-1.0.7-
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Requirement already satisfied: pandas-datareader<0.6,>=0.2.1 in /opt/conda/lib/python3.6/site-pa
Requirement already satisfied: click>=4.0.0 in /opt/conda/lib/python3.6/site-packages (from zipl
Requirement already satisfied: lru-dict>=1.1.4 in /opt/conda/lib/python3.6/site-packages (from z
Requirement already satisfied: MarkupSafe>=0.23 in /opt/conda/lib/python3.6/site-packages (from
Requirement already satisfied: bcolz<1,>=0.12.1 in /opt/conda/lib/python3.6/site-packages (from
Requirement already satisfied: alembic>=0.7.7 in /opt/conda/lib/python3.6/site-packages (from zi
Requirement already satisfied: networkx<2.0,>=1.9.1 in /opt/conda/lib/python3.6/site-packages (f
Requirement already satisfied: traitlets>=4.2 in /opt/conda/lib/python3.6/site-packages (from IP
Requirement already satisfied: pexpect; sys_platform != "win32" in /opt/conda/lib/python3.6/site
Requirement already satisfied: pygments in /opt/conda/lib/python3.6/site-packages (from IPython>
Requirement already satisfied: backcall in /opt/conda/lib/python3.6/site-packages (from IPython>
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Requirement already satisfied: prompt-toolkit<2.0.0,>=1.0.15 in /opt/conda/lib/python3.6/site-pa
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Requirement already satisfied: future in /opt/conda/lib/python3.6/site-packages (from osqp->cvxp
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Requirement already satisfied: jupyter-core in /opt/conda/lib/python3.6/site-packages (from nbfo
Requirement already satisfied: jsonschema!=2.5.0,>=2.4 in /opt/conda/lib/python3.6/site-packages
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Requirement already satisfied: requests-ftp in /opt/conda/lib/python3.6/site-packages (from pand
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Requirement already satisfied: ptyprocess>=0.5 in /opt/conda/lib/python3.6/site-packages (from p
Requirement already satisfied: wcwidth in /opt/conda/lib/python3.6/site-packages (from prompt-to
You are using pip version 9.0.1, however version 18.1 is available.You should consider upgrading
```

1.2.2 Load Packages

```
In [2]: import cvxpy as cvx
        import numpy as np
        import pandas as pd
        import time
        import project_tests
        import project_helper

        import matplotlib.pyplot as plt
        %matplotlib inline
        plt.style.use('ggplot')
        plt.rcParams['figure.figsize'] = (14, 8)


        ---------------------------------------------------------------------------

        RuntimeError                                 Traceback (most recent call last)

        RuntimeError: module compiled against API version 0xc but this version of numpy is 0xb
```

1.3 Data Bundle

We'll be using Zipline to handle our data. We've created a end of day data bundle for this project. Run the cell below to register this data bundle in zipline.

```
In [3]: import os
        import project_helper
        from zipline.data import bundles

        os.environ['ZIPLINE_ROOT'] = os.path.join(os.getcwd(), '..', '..', 'data', 'project_4_eo

        ingest_func = bundles.csvdir.csvdir_equities(['daily'], project_helper.EOD_BUNDLE_NAME)
```

```
        bundles.register(project_helper.EOD_BUNDLE_NAME, ingest_func)

        print('Data Registered')
```

```
Data Registered
```

1.4 Build Pipeline Engine

We'll be using Zipline's pipeline package to access our data for this project. To use it, we must build a pipeline engine. Run the cell below to build the engine.

```
In [4]: from zipline.pipeline import Pipeline
        from zipline.pipeline.factors import AverageDollarVolume
        from zipline.utils.calendars import get_calendar


        universe = AverageDollarVolume(window_length=120).top(500)
        trading_calendar = get_calendar('NYSE')
        bundle_data = bundles.load(project_helper.EOD_BUNDLE_NAME)
        engine = project_helper.build_pipeline_engine(bundle_data, trading_calendar)
```

1.4.1 View Data

With the pipeline engine built, let's get the stocks at the end of the period in the universe we're using. We'll use these tickers to generate the returns data for the our risk model.

```
In [5]: universe_end_date = pd.Timestamp('2016-01-05', tz='UTC')

        universe_tickers = engine\
            .run_pipeline(
                Pipeline(screen=universe),
                universe_end_date,
                universe_end_date)\
            .index.get_level_values(1)\
            .values.tolist()

        universe_tickers
```

```
Out[5]: [Equity(0 [A]),
         Equity(1 [AAL]),
         Equity(2 [AAP]),
         Equity(3 [AAPL]),
         Equity(4 [ABBV]),
         Equity(5 [ABC]),
         Equity(6 [ABT]),
         Equity(7 [ACN]),
         Equity(8 [ADBE]),
         Equity(9 [ADI]),
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Equity(26 [ALGN]),
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Equity(28 [ALL]),
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Equity(104 [CNP]),
Equity(105 [COF]),
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Equity(450 [USB]),
Equity(451 [UTX]),
Equity(452 [V]),
Equity(453 [VAR]),
Equity(454 [VFC]),
Equity(455 [VIAB]),
Equity(456 [VLO]),
Equity(457 [VMC]),
Equity(458 [VNO]),
Equity(459 [VRSK]),
Equity(460 [VRSN]),
Equity(461 [VRTX]),
Equity(462 [VTR]),
Equity(463 [VZ]),
Equity(464 [WAT]),
Equity(465 [WBA]),
Equity(466 [WDC]),
Equity(467 [WEC]),
Equity(468 [WFC]),
Equity(469 [WHR]),
Equity(471 [WM]),
Equity(472 [WMB]),
Equity(473 [WMT]),
Equity(474 [WRK]),
Equity(475 [WU]),
Equity(476 [WY]),
Equity(477 [WYN]),
Equity(478 [WYNN]),
Equity(479 [XEC]),
Equity(480 [XEL]),
Equity(481 [XL]),
Equity(482 [XLNX]),
Equity(483 [XOM]),
Equity(484 [XRAY]),
Equity(485 [XRX]),
Equity(486 [XYL]),
Equity(487 [YUM]),
Equity(488 [ZBH]),
Equity(489 [ZION]),
Equity(490 [ZTS])]
```

1.5 Get Returns

Not that we have our pipeline built, let's access the returns data. We'll start by building a data portal.

```
In [6]: from zipline.data.data_portal import DataPortal


        data_portal = DataPortal(
            bundle_data.asset_finder,
            trading_calendar=trading_calendar,
            first_trading_day=bundle_data.equity_daily_bar_reader.first_trading_day,
            equity_minute_reader=None,
            equity_daily_reader=bundle_data.equity_daily_bar_reader,
            adjustment_reader=bundle_data.adjustment_reader)
```

To make the code easier to read, we've built the helper function `get_pricing` to get the pricing from the data portal.

```
In [7]: def get_pricing(data_portal, trading_calendar, assets, start_date, end_date, field='clos
            end_dt = pd.Timestamp(end_date.strftime('%Y-%m-%d'), tz='UTC', offset='C')
            start_dt = pd.Timestamp(start_date.strftime('%Y-%m-%d'), tz='UTC', offset='C')

            end_loc = trading_calendar.closes.index.get_loc(end_dt)
            start_loc = trading_calendar.closes.index.get_loc(start_dt)

            return data_portal.get_history_window(
                assets=assets,
                end_dt=end_dt,
                bar_count=end_loc - start_loc,
                frequency='1d',
                field=field,
                data_frequency='daily')
```

1.5.1 View Data

Let's get returns data for our risk model using the `get_pricing` function. For this model, we'll be looking back to 5 years of data.

```
In [8]: five_year_returns = \
            get_pricing(
                data_portal,
                trading_calendar,
                universe_tickers,
                universe_end_date - pd.DateOffset(years=5),
                universe_end_date)\
            .pct_change()[1:].fillna(0)

        five_year_returns
```

Out[8]:

	Equity(0 [A])	Equity(1 [AAL])	Equity(2 [AAP])	\
2011-01-07 00:00:00+00:00	0.00843652	0.01423027	0.02670202	
2011-01-10 00:00:00+00:00	-0.00417428	0.00619534	0.00743543	
2011-01-11 00:00:00+00:00	-0.00188630	-0.04364361	-0.00592730	
2011-01-12 00:00:00+00:00	0.01725375	-0.00823708	0.01338721	
2011-01-13 00:00:00+00:00	-0.00455851	0.00095465	0.00303109	
2011-01-14 00:00:00+00:00	0.00343886	-0.00915594	0.00302193	
2011-01-18 00:00:00+00:00	0.03425353	-0.06208490	-0.00428562	
2011-01-19 00:00:00+00:00	-0.01022379	-0.00892857	0.00875376	
2011-01-20 00:00:00+00:00	-0.00849568	0.02195299	-0.00473189	
2011-01-21 00:00:00+00:00	0.00787281	-0.04103759	0.00554409	
2011-01-24 00:00:00+00:00	0.01464622	0.02747253	-0.00110591	
2011-01-25 00:00:00+00:00	-0.00673624	0.00298231	0.00914590	
2011-01-26 00:00:00+00:00	-0.03073582	0.06613350	0.00359340	
2011-01-27 00:00:00+00:00	0.00772081	0.02317753	-0.00155262	
2011-01-28 00:00:00+00:00	-0.01884631	-0.08055268	-0.00093620	
2011-01-31 00:00:00+00:00	0.00360809	-0.02361480	-0.00235062	
2011-02-01 00:00:00+00:00	0.01165376	-0.00104701	-0.00921769	
2011-02-02 00:00:00+00:00	0.01011176	-0.03930406	-0.02747650	
2011-02-03 00:00:00+00:00	-0.00028893	0.00730962	0.01412639	
2011-02-04 00:00:00+00:00	0.00562724	-0.03649951	0.02401434	
2011-02-07 00:00:00+00:00	0.00770895	0.05204586	0.00811404	
2011-02-08 00:00:00+00:00	0.01085425	0.01645475	0.00620226	
2011-02-09 00:00:00+00:00	0.00466351	0.00000000	0.01695500	
2011-02-10 00:00:00+00:00	0.00041298	-0.00304846	-0.01136679	
2011-02-11 00:00:00+00:00	-0.00714982	0.02836356	0.00076442	
2011-02-14 00:00:00+00:00	0.00166312	-0.01579001	-0.02327358	
2011-02-15 00:00:00+00:00	-0.01190476	0.01104282	-0.00392614	
2011-02-16 00:00:00+00:00	0.01512325	0.00195775	0.01385974	
2011-02-17 00:00:00+00:00	-0.00331066	-0.01779103	-0.02484354	
2011-02-18 00:00:00+00:00	0.01107771	-0.02010261	-0.00669325	
...	...	...	...	
2015-11-20 00:00:00+00:00	0.00107212	-0.00237346	0.00276686	
2015-11-23 00:00:00+00:00	-0.00709429	0.00237910	-0.00122838	
2015-11-24 00:00:00+00:00	0.00208486	-0.02530879	0.00350426	
2015-11-25 00:00:00+00:00	-0.00820649	0.00193813	0.00680544	
2015-11-27 00:00:00+00:00	-0.00325586	0.00920070	0.00328491	
2015-11-30 00:00:00+00:00	-0.01020870	-0.01032093	-0.01279784	
2015-12-01 00:00:00+00:00	0.01574786	0.04849282	-0.00239635	
2015-12-02 00:00:00+00:00	-0.00528420	0.01293012	-0.02716607	
2015-12-03 00:00:00+00:00	-0.00952117	-0.01255465	-0.01994438	
2015-12-04 00:00:00+00:00	0.02019919	0.03930296	0.00677909	
2015-12-07 00:00:00+00:00	-0.00033987	0.01801987	-0.02957813	
2015-12-08 00:00:00+00:00	-0.02330712	-0.02687583	-0.00886608	
2015-12-09 00:00:00+00:00	-0.00516964	-0.02021340	0.02222267	
2015-12-10 00:00:00+00:00	0.01503860	0.01009224	-0.00946596	
2015-12-11 00:00:00+00:00	-0.01222670	-0.04535632	-0.01917906	
2015-12-14 00:00:00+00:00	-0.01119741	-0.00761835	-0.00832534	

```
2015-12-15 00:00:00+00:00     0.02468348       0.01976847       0.05799045
2015-12-16 00:00:00+00:00     0.01078027       0.01419020       0.02977102
2015-12-17 00:00:00+00:00    -0.01721238      -0.01712199      -0.04819014
2015-12-18 00:00:00+00:00    -0.04108447      -0.03225884      -0.02286262
2015-12-21 00:00:00+00:00     0.00945523       0.03186317       0.00053085
2015-12-22 00:00:00+00:00     0.01050225       0.01167033      -0.01175973
2015-12-23 00:00:00+00:00     0.01180348       0.00921901       0.00832501
2015-12-24 00:00:00+00:00    -0.00368236       0.01202196       0.00046505
2015-12-28 00:00:00+00:00     0.00704030      -0.01325882       0.00952567
2015-12-29 00:00:00+00:00     0.01944279       0.00625637       0.01095726
2015-12-30 00:00:00+00:00    -0.00638405      -0.01608535      -0.00525423
2015-12-31 00:00:00+00:00    -0.01243206      -0.01053186      -0.00587919
2016-01-04 00:00:00+00:00    -0.02828157      -0.03398810       0.01149418
2016-01-05 00:00:00+00:00     0.00405845      -0.00954098      -0.00683002

                           Equity(3 [AAPL])  Equity(4 [ABBV])  \
2011-01-07 00:00:00+00:00         0.00714639        0.00000000
2011-01-10 00:00:00+00:00         0.01885158        0.00000000
2011-01-11 00:00:00+00:00        -0.00236744        0.00000000
2011-01-12 00:00:00+00:00         0.00813289        0.00000000
2011-01-13 00:00:00+00:00         0.00365656        0.00000000
2011-01-14 00:00:00+00:00         0.00810620        0.00000000
2011-01-18 00:00:00+00:00        -0.02247419        0.00000000
2011-01-19 00:00:00+00:00        -0.00531448        0.00000000
2011-01-20 00:00:00+00:00        -0.01818900        0.00000000
2011-01-21 00:00:00+00:00        -0.01791080        0.00000000
2011-01-24 00:00:00+00:00         0.03283704        0.00000000
2011-01-25 00:00:00+00:00         0.01170955        0.00000000
2011-01-26 00:00:00+00:00         0.00719342        0.00000000
2011-01-27 00:00:00+00:00        -0.00187707        0.00000000
2011-01-28 00:00:00+00:00        -0.02070958        0.00000000
2011-01-31 00:00:00+00:00         0.00957845        0.00000000
2011-02-01 00:00:00+00:00         0.01681783        0.00000000
2011-02-02 00:00:00+00:00        -0.00205320        0.00000000
2011-02-03 00:00:00+00:00        -0.00256035        0.00000000
2011-02-04 00:00:00+00:00         0.00891547        0.00000000
2011-02-07 00:00:00+00:00         0.01553804        0.00000000
2011-02-08 00:00:00+00:00         0.00943966        0.00000000
2011-02-09 00:00:00+00:00         0.00833204        0.00000000
2011-02-10 00:00:00+00:00        -0.01010922        0.00000000
2011-02-11 00:00:00+00:00         0.00650490        0.00000000
2011-02-14 00:00:00+00:00         0.00652903        0.00000000
2011-02-15 00:00:00+00:00         0.00201613        0.00000000
2011-02-16 00:00:00+00:00         0.00896684        0.00000000
2011-02-17 00:00:00+00:00        -0.01330906        0.00000000
2011-02-18 00:00:00+00:00        -0.02159490        0.00000000
...                                      ...               ...
2015-11-20 00:00:00+00:00         0.00438086        0.00925624
```

2015-11-23 00:00:00+00:00	-0.01298872	0.00064612
2015-11-24 00:00:00+00:00	0.00959410	-0.00032285
2015-11-25 00:00:00+00:00	-0.00715141	-0.01374361
2015-11-27 00:00:00+00:00	-0.00186283	-0.00480271
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2015-12-01 00:00:00+00:00	-0.00811576	0.01495718
2015-12-02 00:00:00+00:00	-0.00902983	-0.02202152
2015-12-03 00:00:00+00:00	-0.00929219	-0.02772394
2015-12-04 00:00:00+00:00	0.03324578	0.01889890
2015-12-07 00:00:00+00:00	-0.00629799	-0.01592051
2015-12-08 00:00:00+00:00	-0.00042489	0.00711446
2015-12-09 00:00:00+00:00	-0.02207699	-0.01130272
2015-12-10 00:00:00+00:00	0.00476320	-0.00446315
2015-12-11 00:00:00+00:00	-0.02573993	-0.03118548
2015-12-14 00:00:00+00:00	-0.00618871	0.02589759
2015-12-15 00:00:00+00:00	-0.01768577	0.01713257
2015-12-16 00:00:00+00:00	0.00768495	0.02199833
2015-12-17 00:00:00+00:00	-0.02119576	-0.02169610
2015-12-18 00:00:00+00:00	-0.02706364	-0.01134153
2015-12-21 00:00:00+00:00	0.01225425	0.00824462
2015-12-22 00:00:00+00:00	-0.00092672	0.02474629
2015-12-23 00:00:00+00:00	0.01286896	0.01717833
2015-12-24 00:00:00+00:00	-0.00534053	-0.00204082
2015-12-28 00:00:00+00:00	-0.01120361	0.00495300
2015-12-29 00:00:00+00:00	0.01797599	0.01191076
2015-12-30 00:00:00+00:00	-0.01305616	0.00590373
2015-12-31 00:00:00+00:00	-0.01919944	-0.00937219
2016-01-04 00:00:00+00:00	0.00085542	-0.02751240
2016-01-05 00:00:00+00:00	-0.02505441	-0.00416936

	Equity(5 [ABC])	Equity(6 [ABT])	Equity(7 [ACN])	\
2011-01-07 00:00:00+00:00	0.00199434	0.00416541	0.00164769	
2011-01-10 00:00:00+00:00	-0.00571429	-0.00889600	-0.00885384	
2011-01-11 00:00:00+00:00	0.00978303	-0.00206747	0.01371668	
2011-01-12 00:00:00+00:00	-0.00597922	-0.00101061	0.02296913	
2011-01-13 00:00:00+00:00	0.01492537	-0.00445119	-0.00040011	
2011-01-14 00:00:00+00:00	0.00139452	-0.01011076	0.00259000	
2011-01-18 00:00:00+00:00	0.02088872	0.00662116	0.00699843	
2011-01-19 00:00:00+00:00	-0.01714410	0.00275342	-0.00296182	
2011-01-20 00:00:00+00:00	0.00479450	0.01332249	0.01871257	
2011-01-21 00:00:00+00:00	0.01064197	-0.00085307	-0.00195169	
2011-01-24 00:00:00+00:00	0.00524943	0.00522324	0.00842018	
2011-01-25 00:00:00+00:00	-0.00936254	-0.00434674	0.00485935	
2011-01-26 00:00:00+00:00	0.01222707	-0.02524087	0.01219180	
2011-01-27 00:00:00+00:00	0.01183286	-0.00792793	0.00017944	
2011-01-28 00:00:00+00:00	-0.02226215	-0.01919983	-0.01603463	
2011-01-31 00:00:00+00:00	-0.00389347	-0.00724829	-0.00098003	
2011-02-01 00:00:00+00:00	0.01197624	0.00154551	0.01749823	

2011-02-02 00:00:00+00:00	-0.02119705	0.01106795	0.00363229
2011-02-03 00:00:00+00:00	-0.00366196	0.00589443	0.00417765
2011-02-04 00:00:00+00:00	0.03304712	0.00261602	-0.00436050
2011-02-07 00:00:00+00:00	-0.00217765	-0.00934092	0.00227918
2011-02-08 00:00:00+00:00	0.00218240	-0.00173831	-0.00055735
2011-02-09 00:00:00+00:00	0.00300577	-0.00153026	0.00113763
2011-02-10 00:00:00+00:00	0.00110085	-0.00110982	0.00550344
2011-02-11 00:00:00+00:00	-0.00137455	0.00153431	-0.01114607
2011-02-14 00:00:00+00:00	0.00575047	0.00924459	0.00020168
2011-02-15 00:00:00+00:00	-0.00732946	0.01674954	-0.00802079
2011-02-16 00:00:00+00:00	-0.00355392	-0.01050193	0.02732858
2011-02-17 00:00:00+00:00	0.02914771	0.00130066	0.01178385
2011-02-18 00:00:00+00:00	0.00961998	0.01210641	-0.00795272
...	...	...	...
2015-11-20 00:00:00+00:00	-0.00090483	0.00611281	0.00643014
2015-11-23 00:00:00+00:00	-0.00372792	-0.01238148	-0.00120585
2015-11-24 00:00:00+00:00	-0.00233603	0.00020972	-0.00453713
2015-11-25 00:00:00+00:00	0.00436515	-0.00086201	-0.00233759
2015-11-27 00:00:00+00:00	0.00061184	0.00020986	0.00336265
2015-11-30 00:00:00+00:00	-0.00354229	-0.01100361	-0.00222774
2015-12-01 00:00:00+00:00	0.00871792	0.01202178	0.00848039
2015-12-02 00:00:00+00:00	-0.00653437	-0.00528731	-0.00499107
2015-12-03 00:00:00+00:00	-0.00141471	-0.02365007	-0.01542891
2015-12-04 00:00:00+00:00	0.01195750	0.02604566	0.02992398
2015-12-07 00:00:00+00:00	0.00089849	0.00572671	-0.00146283
2015-12-08 00:00:00+00:00	0.00490595	-0.00020917	-0.00027950
2015-12-09 00:00:00+00:00	0.00198396	-0.01294807	-0.01487559
2015-12-10 00:00:00+00:00	0.01271990	0.00777184	0.00289674
2015-12-11 00:00:00+00:00	0.00127956	-0.02096235	-0.02137978
2015-12-14 00:00:00+00:00	0.00440628	0.01014465	0.01007090
2015-12-15 00:00:00+00:00	-0.00819372	0.01741535	0.00338602
2015-12-16 00:00:00+00:00	-0.00098521	0.01007990	0.02210700
2015-12-17 00:00:00+00:00	0.00738610	-0.01715337	-0.05335502
2015-12-18 00:00:00+00:00	-0.00449706	-0.03446098	-0.01288309
2015-12-21 00:00:00+00:00	0.00991570	0.00777786	0.01040390
2015-12-22 00:00:00+00:00	0.00261687	0.00997788	0.00747281
2015-12-23 00:00:00+00:00	0.00756710	0.01395006	0.00636498
2015-12-24 00:00:00+00:00	0.00009036	0.00000000	-0.00181999
2015-12-28 00:00:00+00:00	0.00230910	-0.00154955	-0.00144052
2015-12-29 00:00:00+00:00	0.00556913	0.01754180	0.01191401
2015-12-30 00:00:00+00:00	0.00239063	-0.01201673	0.00512422
2015-12-31 00:00:00+00:00	-0.01248112	-0.00795266	-0.01284442
2016-01-04 00:00:00+00:00	-0.01774070	-0.04406668	-0.02555086
2016-01-05 00:00:00+00:00	0.01462920	-0.00024665	0.00520704

	Equity(8 [ADBE])	Equity(9 [ADI])	\
2011-01-07 00:00:00+00:00	-0.00712736	-0.00581846	
2011-01-10 00:00:00+00:00	0.02871411	0.00292626	

2011-01-11 00:00:00+00:00	0.00060680	0.00875316
2011-01-12 00:00:00+00:00	0.01795027	0.00025710
2011-01-13 00:00:00+00:00	-0.00571905	-0.00501221
2011-01-14 00:00:00+00:00	0.01228280	0.01982692
2011-01-18 00:00:00+00:00	0.01154188	0.03264518
2011-01-19 00:00:00+00:00	-0.00789936	-0.02057462
2011-01-20 00:00:00+00:00	-0.01238573	-0.00281761
2011-01-21 00:00:00+00:00	-0.00656913	-0.00411277
2011-01-24 00:00:00+00:00	0.02284340	0.01497431
2011-01-25 00:00:00+00:00	-0.01381134	-0.01450491
2011-01-26 00:00:00+00:00	-0.00119190	0.00283652
2011-01-27 00:00:00+00:00	0.00984487	0.00747981
2011-01-28 00:00:00+00:00	-0.04017725	-0.02245999
2011-01-31 00:00:00+00:00	0.01723607	0.01381753
2011-02-01 00:00:00+00:00	0.01391831	0.02162417
2011-02-02 00:00:00+00:00	-0.00238735	0.00227994
2011-02-03 00:00:00+00:00	0.00299133	-0.01334112
2011-02-04 00:00:00+00:00	-0.00507009	0.01965916
2011-02-07 00:00:00+00:00	0.00599520	-0.00351381
2011-02-08 00:00:00+00:00	0.00029797	-0.00600987
2011-02-09 00:00:00+00:00	-0.01668156	0.00478144
2011-02-10 00:00:00+00:00	0.01696456	0.00451308
2011-02-11 00:00:00+00:00	0.00297885	0.01500657
2011-02-14 00:00:00+00:00	0.00564301	0.00987654
2011-02-15 00:00:00+00:00	0.00236267	0.00023854
2011-02-16 00:00:00+00:00	0.02209782	-0.00390509
2011-02-17 00:00:00+00:00	0.00835976	0.00855903
2011-02-18 00:00:00+00:00	0.01172098	-0.00169134
...	...	...
2015-11-20 00:00:00+00:00	0.00054490	-0.00584294
2015-11-23 00:00:00+00:00	0.00163381	-0.04410655
2015-11-24 00:00:00+00:00	0.00043497	0.06374097
2015-11-25 00:00:00+00:00	-0.00250000	-0.00281048
2015-11-27 00:00:00+00:00	0.00435872	0.00331472
2015-11-30 00:00:00+00:00	-0.00770316	0.01952228
2015-12-01 00:00:00+00:00	0.01191778	-0.00097042
2015-12-02 00:00:00+00:00	-0.00572663	-0.00699034
2015-12-03 00:00:00+00:00	-0.02292980	-0.02782630
2015-12-04 00:00:00+00:00	0.02969636	0.00271314
2015-12-07 00:00:00+00:00	-0.03218838	-0.01198796
2015-12-08 00:00:00+00:00	0.02366071	-0.00821590
2015-12-09 00:00:00+00:00	-0.02354993	-0.02360837
2015-12-10 00:00:00+00:00	-0.00669942	0.00882138
2015-12-11 00:00:00+00:00	0.02765288	-0.00384301
2015-12-14 00:00:00+00:00	0.02012689	-0.00193824
2015-12-15 00:00:00+00:00	0.00814926	-0.00474296
2015-12-16 00:00:00+00:00	0.01637949	0.01733616
2015-12-17 00:00:00+00:00	-0.01423190	-0.02450989

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2015-12-18 00:00:00+00:00       -0.03067941      -0.01693954
2015-12-21 00:00:00+00:00        0.00339503       0.01196200
2015-12-22 00:00:00+00:00        0.02401222       0.00332573
2015-12-23 00:00:00+00:00        0.00937966       0.00829624
2015-12-24 00:00:00+00:00       -0.00422386       0.00567317
2015-12-28 00:00:00+00:00       -0.00106045      -0.00616419
2015-12-29 00:00:00+00:00        0.01199575       0.01522413
2015-12-30 00:00:00+00:00       -0.00052449      -0.01325558
2015-12-31 00:00:00+00:00       -0.01406381      -0.02174525
2016-01-04 00:00:00+00:00       -0.02097083      -0.01591868
2016-01-05 00:00:00+00:00        0.00402305      -0.00734750

                                      ...          Equity(481 [XL])  \
2011-01-07 00:00:00+00:00             ...               -0.00183775
2011-01-10 00:00:00+00:00             ...                0.00094687
2011-01-11 00:00:00+00:00             ...                0.00131385
2011-01-12 00:00:00+00:00             ...                0.00498609
2011-01-13 00:00:00+00:00             ...                0.03049927
2011-01-14 00:00:00+00:00             ...                0.02660653
2011-01-18 00:00:00+00:00             ...                0.00167843
2011-01-19 00:00:00+00:00             ...               -0.01483416
2011-01-20 00:00:00+00:00             ...               -0.02451226
2011-01-21 00:00:00+00:00             ...                0.00000000
2011-01-24 00:00:00+00:00             ...                0.01235897
2011-01-25 00:00:00+00:00             ...                0.00217821
2011-01-26 00:00:00+00:00             ...                0.00262839
2011-01-27 00:00:00+00:00             ...                0.01426699
2011-01-28 00:00:00+00:00             ...               -0.02564740
2011-01-31 00:00:00+00:00             ...                0.00484620
2011-02-01 00:00:00+00:00             ...                0.01568687
2011-02-02 00:00:00+00:00             ...               -0.01284550
2011-02-03 00:00:00+00:00             ...                0.01043038
2011-02-04 00:00:00+00:00             ...                0.00947084
2011-02-07 00:00:00+00:00             ...                0.00680069
2011-02-08 00:00:00+00:00             ...                0.00384577
2011-02-09 00:00:00+00:00             ...               -0.01183694
2011-02-10 00:00:00+00:00             ...               -0.00894677
2011-02-11 00:00:00+00:00             ...                0.00170520
2011-02-14 00:00:00+00:00             ...               -0.01161568
2011-02-15 00:00:00+00:00             ...               -0.00607872
2011-02-16 00:00:00+00:00             ...                0.00917384
2011-02-17 00:00:00+00:00             ...                0.01565577
2011-02-18 00:00:00+00:00             ...                0.05340361
...                                   ...                       ...
2015-11-20 00:00:00+00:00             ...                0.00813121
2015-11-23 00:00:00+00:00             ...               -0.00469574
2015-11-24 00:00:00+00:00             ...               -0.00077707
2015-11-25 00:00:00+00:00             ...               -0.00888765
```

```
2015-11-27 00:00:00+00:00        ...                0.00473588
2015-11-30 00:00:00+00:00        ...                0.00421152
2015-12-01 00:00:00+00:00        ...                0.01519233
2015-12-02 00:00:00+00:00        ...               -0.00385752
2015-12-03 00:00:00+00:00        ...               -0.00829420
2015-12-04 00:00:00+00:00        ...                0.02221053
2015-12-07 00:00:00+00:00        ...                0.00000000
2015-12-08 00:00:00+00:00        ...               -0.00460567
2015-12-09 00:00:00+00:00        ...               -0.01309164
2015-12-10 00:00:00+00:00        ...               -0.00675676
2015-12-11 00:00:00+00:00        ...               -0.01493822
2015-12-14 00:00:00+00:00        ...                0.00721594
2015-12-15 00:00:00+00:00        ...                0.01539193
2015-12-16 00:00:00+00:00        ...                0.00471295
2015-12-17 00:00:00+00:00        ...               -0.00156361
2015-12-18 00:00:00+00:00        ...               -0.01901256
2015-12-21 00:00:00+00:00        ...                0.00635765
2015-12-22 00:00:00+00:00        ...                0.03167093
2015-12-23 00:00:00+00:00        ...                0.00919881
2015-12-24 00:00:00+00:00        ...                0.00962284
2015-12-28 00:00:00+00:00        ...                0.00050303
2015-12-29 00:00:00+00:00        ...                0.01381318
2015-12-30 00:00:00+00:00        ...               -0.01461683
2015-12-31 00:00:00+00:00        ...               -0.01605213
2016-01-04 00:00:00+00:00        ...               -0.02476714
2016-01-05 00:00:00+00:00        ...                0.00209794

                           Equity(482 [XLNX])  Equity(483 [XOM])  \
2011-01-07 00:00:00+00:00         -0.00561865         0.00546091
2011-01-10 00:00:00+00:00          0.00781438        -0.00608100
2011-01-11 00:00:00+00:00          0.01017933         0.00744242
2011-01-12 00:00:00+00:00          0.01566621         0.01176334
2011-01-13 00:00:00+00:00         -0.00321668         0.00169383
2011-01-14 00:00:00+00:00          0.02589425         0.01474258
2011-01-18 00:00:00+00:00          0.00250133         0.01116324
2011-01-19 00:00:00+00:00         -0.02358990        -0.00596800
2011-01-20 00:00:00+00:00          0.00774353        -0.00626137
2011-01-21 00:00:00+00:00          0.00061472         0.01582494
2011-01-24 00:00:00+00:00          0.01601137        -0.00494300
2011-01-25 00:00:00+00:00          0.00627338         0.00115375
2011-01-26 00:00:00+00:00          0.00593383         0.01245258
2011-01-27 00:00:00+00:00          0.02116856         0.00275077
2011-01-28 00:00:00+00:00         -0.02010822        -0.01113056
2011-01-31 00:00:00+00:00          0.00029849         0.02139566
2011-02-01 00:00:00+00:00          0.03200298         0.04003746
2011-02-02 00:00:00+00:00         -0.00451785        -0.00595828
2011-02-03 00:00:00+00:00         -0.00816904         0.00034726
2011-02-04 00:00:00+00:00          0.02470898        -0.00191681
```

```
2011-02-07 00:00:00+00:00         -0.00507270         0.00780293
2011-02-08 00:00:00+00:00          0.00179527        -0.00607698
2011-02-09 00:00:00+00:00         -0.00179205        -0.00517814
2011-02-10 00:00:00+00:00          0.00391368         0.00787593
2011-02-11 00:00:00+00:00          0.01076538        -0.00456215
2011-02-14 00:00:00+00:00          0.00031846         0.02522953
2011-02-15 00:00:00+00:00         -0.00180403        -0.02285301
2011-02-16 00:00:00+00:00          0.00386265         0.00868160
2011-02-17 00:00:00+00:00          0.00031771         0.00227521
2011-02-18 00:00:00+00:00          0.00144687         0.00739258
...                                       ...                ...
2015-11-20 00:00:00+00:00          0.00041182        -0.00635194
2015-11-23 00:00:00+00:00         -0.00695468         0.00613134
2015-11-24 00:00:00+00:00          0.01295953         0.01993523
2015-11-25 00:00:00+00:00         -0.00445842        -0.00768963
2015-11-27 00:00:00+00:00          0.00447839        -0.00025651
2015-11-30 00:00:00+00:00          0.00934761         0.00529351
2015-12-01 00:00:00+00:00          0.01107484         0.00282087
2015-12-02 00:00:00+00:00         -0.02469292        -0.02857143
2015-12-03 00:00:00+00:00         -0.01081970        -0.01432669
2015-12-04 00:00:00+00:00          0.01032552         0.00573563
2015-12-07 00:00:00+00:00         -0.00879092        -0.02612215
2015-12-08 00:00:00+00:00         -0.00391018        -0.02825109
2015-12-09 00:00:00+00:00         -0.00993443         0.01338977
2015-12-10 00:00:00+00:00          0.00188278         0.00079770
2015-12-11 00:00:00+00:00         -0.01271252        -0.01783980
2015-12-14 00:00:00+00:00         -0.00094052         0.02273800
2015-12-15 00:00:00+00:00          0.01351594         0.04471023
2015-12-16 00:00:00+00:00          0.00053077        -0.00352152
2015-12-17 00:00:00+00:00         -0.01814726        -0.01503666
2015-12-18 00:00:00+00:00         -0.01231427        -0.00872355
2015-12-21 00:00:00+00:00          0.01677569        -0.00025549
2015-12-22 00:00:00+00:00          0.00273487         0.00505438
2015-12-23 00:00:00+00:00          0.00950124         0.03270236
2015-12-24 00:00:00+00:00         -0.00062007        -0.01072430
2015-12-28 00:00:00+00:00         -0.00106364        -0.00743906
2015-12-29 00:00:00+00:00          0.00796362         0.00533553
2015-12-30 00:00:00+00:00         -0.00706442        -0.01326109
2015-12-31 00:00:00+00:00         -0.01817456        -0.00205030
2016-01-04 00:00:00+00:00         -0.02492212        -0.00627612
2016-01-05 00:00:00+00:00          0.01486318         0.00851070

                           Equity(484 [XRAY])  Equity(485 [XRX])  \
2011-01-07 00:00:00+00:00         -0.00404361        -0.01395259
2011-01-10 00:00:00+00:00          0.01046585         0.00973303
2011-01-11 00:00:00+00:00          0.00735141         0.00611644
2011-01-12 00:00:00+00:00          0.02718194         0.00438630
2011-01-13 00:00:00+00:00          0.00054651        -0.01823475
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2011-01-14 00:00:00+00:00	-0.00028748	0.02649446
2011-01-18 00:00:00+00:00	0.01158879	0.00604402
2011-01-19 00:00:00+00:00	-0.01989880	-0.01284667
2011-01-20 00:00:00+00:00	-0.00084112	-0.03379775
2011-01-21 00:00:00+00:00	-0.00304798	-0.00087153
2011-01-24 00:00:00+00:00	0.00165968	0.00804885
2011-01-25 00:00:00+00:00	0.00113369	0.01514317
2011-01-26 00:00:00+00:00	0.00055168	-0.07629122
2011-01-27 00:00:00+00:00	0.01639630	0.02466443
2011-01-28 00:00:00+00:00	-0.02187072	-0.02222859
2011-01-31 00:00:00+00:00	-0.00756028	0.00661503
2011-02-01 00:00:00+00:00	0.02479485	0.02449777
2011-02-02 00:00:00+00:00	-0.01038976	-0.00182689
2011-02-03 00:00:00+00:00	0.00855568	0.00459592
2011-02-04 00:00:00+00:00	0.00304817	-0.00550607
2011-02-07 00:00:00+00:00	0.00685187	0.00276828
2011-02-08 00:00:00+00:00	0.00518223	-0.00276064
2011-02-09 00:00:00+00:00	-0.01844088	0.00370461
2011-02-10 00:00:00+00:00	0.00551211	-0.00462381
2011-02-11 00:00:00+00:00	0.00714655	0.01202070
2011-02-14 00:00:00+00:00	-0.00544299	0.00547592
2011-02-15 00:00:00+00:00	0.00409742	0.00360404
2011-02-16 00:00:00+00:00	0.00028536	0.02709281
2011-02-17 00:00:00+00:00	-0.00191139	0.00000000
2011-02-18 00:00:00+00:00	0.01314812	-0.00438988
...	...	...
2015-11-20 00:00:00+00:00	0.00279330	0.00289932
2015-11-23 00:00:00+00:00	0.00734514	0.02769219
2015-11-24 00:00:00+00:00	-0.00956300	-0.01299182
2015-11-25 00:00:00+00:00	-0.00279190	-0.00191255
2015-11-27 00:00:00+00:00	0.00263307	0.00379485
2015-11-30 00:00:00+00:00	-0.00736321	-0.00752358
2015-12-01 00:00:00+00:00	0.02160044	0.01327550
2015-12-02 00:00:00+00:00	0.00757240	-0.02996241
2015-12-03 00:00:00+00:00	0.00273291	-0.00095925
2015-12-04 00:00:00+00:00	0.00749501	0.01159888
2015-12-07 00:00:00+00:00	-0.00190007	-0.02957591
2015-12-08 00:00:00+00:00	-0.01206744	-0.00492958
2015-12-09 00:00:00+00:00	-0.02106570	-0.00986868
2015-12-10 00:00:00+00:00	-0.00031695	0.01497042
2015-12-11 00:00:00+00:00	-0.01775464	-0.01279343
2015-12-14 00:00:00+00:00	-0.00183474	-0.01791305
2015-12-15 00:00:00+00:00	0.00435700	0.01622211
2015-12-16 00:00:00+00:00	0.00850674	0.02493746
2015-12-17 00:00:00+00:00	-0.00314212	-0.00778738
2015-12-18 00:00:00+00:00	-0.01045055	-0.00394377
2015-12-21 00:00:00+00:00	0.00703494	0.01477910
2015-12-22 00:00:00+00:00	0.01004736	0.03886271

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2015-12-23 00:00:00+00:00          0.00758616         0.01119292
2015-12-24 00:00:00+00:00         -0.00212741         0.00555290
2015-12-28 00:00:00+00:00          0.00493013        -0.02113809
2015-12-29 00:00:00+00:00          0.01143615         0.01128297
2015-12-30 00:00:00+00:00         -0.00807866         0.00184720
2015-12-31 00:00:00+00:00         -0.00911914        -0.00837082
2016-01-04 00:00:00+00:00         -0.03271090        -0.03105128
2016-01-05 00:00:00+00:00          0.02039022        -0.00195732

                           Equity(486 [XYL])  Equity(487 [YUM])  \
2011-01-07 00:00:00+00:00         0.00000000         0.01245693
2011-01-10 00:00:00+00:00         0.00000000         0.00143979
2011-01-11 00:00:00+00:00         0.00000000        -0.00646974
2011-01-12 00:00:00+00:00         0.00000000         0.00263106
2011-01-13 00:00:00+00:00         0.00000000        -0.00508430
2011-01-14 00:00:00+00:00         0.00000000        -0.02166101
2011-01-18 00:00:00+00:00         0.00000000         0.02945339
2011-01-19 00:00:00+00:00         0.00000000         0.00081838
2011-01-20 00:00:00+00:00         0.00000000        -0.01318157
2011-01-21 00:00:00+00:00         0.00000000        -0.00759032
2011-01-24 00:00:00+00:00         0.00000000         0.00060118
2011-01-25 00:00:00+00:00         0.00000000        -0.00620848
2011-01-26 00:00:00+00:00         0.00000000        -0.00480301
2011-01-27 00:00:00+00:00         0.00000000        -0.00374620
2011-01-28 00:00:00+00:00         0.00000000        -0.02500085
2011-01-31 00:00:00+00:00         0.00000000         0.00774817
2011-02-01 00:00:00+00:00         0.00000000         0.01410150
2011-02-02 00:00:00+00:00         0.00000000         0.00656172
2011-02-03 00:00:00+00:00         0.00000000         0.03141255
2011-02-04 00:00:00+00:00         0.00000000         0.00140817
2011-02-07 00:00:00+00:00         0.00000000         0.00202754
2011-02-08 00:00:00+00:00         0.00000000         0.00385105
2011-02-09 00:00:00+00:00         0.00000000        -0.00182061
2011-02-10 00:00:00+00:00         0.00000000         0.00485295
2011-02-11 00:00:00+00:00         0.00000000         0.00061584
2011-02-14 00:00:00+00:00         0.00000000         0.01065725
2011-02-15 00:00:00+00:00         0.00000000         0.00852564
2011-02-16 00:00:00+00:00         0.00000000         0.00889849
2011-02-17 00:00:00+00:00         0.00000000         0.00390600
2011-02-18 00:00:00+00:00         0.00000000        -0.00411045
...                                      ...                ...
2015-11-20 00:00:00+00:00        -0.00449783         0.01505987
2015-11-23 00:00:00+00:00         0.00132239        -0.00096628
2015-11-24 00:00:00+00:00        -0.00187091        -0.00425172
2015-11-25 00:00:00+00:00         0.00482386         0.00289380
2015-11-27 00:00:00+00:00        -0.00213974         0.00510503
2015-11-30 00:00:00+00:00        -0.00692784        -0.00618325
2015-12-01 00:00:00+00:00         0.00858179         0.02716952
```

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2015-12-02 00:00:00+00:00        -0.01833503         0.00631281
2015-12-03 00:00:00+00:00        -0.00567594        -0.02427203
2015-12-04 00:00:00+00:00         0.02477363         0.04115927
2015-12-07 00:00:00+00:00        -0.01964712         0.00353962
2015-12-08 00:00:00+00:00        -0.01707392        -0.01073476
2015-12-09 00:00:00+00:00        -0.00056952        -0.02367896
2015-12-10 00:00:00+00:00         0.01213779        -0.00825643
2015-12-11 00:00:00+00:00        -0.01306196        -0.02583602
2015-12-14 00:00:00+00:00         0.01158048         0.00490982
2015-12-15 00:00:00+00:00         0.00163542         0.01341047
2015-12-16 00:00:00+00:00         0.02071897         0.01280939
2015-12-17 00:00:00+00:00        -0.02669682        -0.01822419
2015-12-18 00:00:00+00:00        -0.01700150        -0.00499057
2015-12-21 00:00:00+00:00         0.00835952         0.02171387
2015-12-22 00:00:00+00:00         0.00997684        -0.00544780
2015-12-23 00:00:00+00:00         0.01723748         0.01534943
2015-12-24 00:00:00+00:00        -0.00161385        -0.00162043
2015-12-28 00:00:00+00:00        -0.00348374        -0.00217727
2015-12-29 00:00:00+00:00         0.00430697         0.00541538
2015-12-30 00:00:00+00:00        -0.00618212        -0.00578080
2015-12-31 00:00:00+00:00        -0.01003138        -0.01029925
2016-01-04 00:00:00+00:00        -0.01151995        -0.01148918
2016-01-05 00:00:00+00:00        -0.00028634        -0.00249493

                           Equity(488 [ZBH])  Equity(489 [ZION])  \
2011-01-07 00:00:00+00:00         -0.00018145         -0.01045802
2011-01-10 00:00:00+00:00          0.00778351         -0.01794496
2011-01-11 00:00:00+00:00          0.03567570          0.00746728
2011-01-12 00:00:00+00:00          0.01474083         -0.01190269
2011-01-13 00:00:00+00:00         -0.00466453         -0.00917796
2011-01-14 00:00:00+00:00          0.00594885          0.03317747
2011-01-18 00:00:00+00:00          0.00699753         -0.00853448
2011-01-19 00:00:00+00:00         -0.00409759         -0.01843318
2011-01-20 00:00:00+00:00         -0.00161165         -0.00797236
2011-01-21 00:00:00+00:00          0.00932467          0.02402000
2011-01-24 00:00:00+00:00         -0.01650140         -0.02302058
2011-01-25 00:00:00+00:00          0.01714176         -0.00883613
2011-01-26 00:00:00+00:00         -0.01952376         -0.01062584
2011-01-27 00:00:00+00:00          0.06875384          0.02016019
2011-01-28 00:00:00+00:00         -0.00847214         -0.01387340
2011-01-31 00:00:00+00:00          0.00990224          0.00637836
2011-02-01 00:00:00+00:00          0.01774607          0.03097047
2011-02-02 00:00:00+00:00          0.00516054         -0.00370596
2011-02-03 00:00:00+00:00         -0.00033292         -0.00039386
2011-02-04 00:00:00+00:00          0.00247147          0.01611067
2011-02-07 00:00:00+00:00         -0.01087565          0.02761741
2011-02-08 00:00:00+00:00         -0.00049496          0.00477967
2011-02-09 00:00:00+00:00         -0.00985108         -0.00475694
```

2011-02-10 00:00:00+00:00	0.01144950	-0.02649784
2011-02-11 00:00:00+00:00	0.00965987	0.01425557
2011-02-14 00:00:00+00:00	0.00248369	-0.01002123
2011-02-15 00:00:00+00:00	-0.00181453	-0.00446084
2011-02-16 00:00:00+00:00	0.01055741	0.00120638
2011-02-17 00:00:00+00:00	0.01532474	-0.00322747
2011-02-18 00:00:00+00:00	0.02378154	-0.01795968
...	...	...
2015-11-20 00:00:00+00:00	-0.00317570	0.00000000
2015-11-23 00:00:00+00:00	-0.00858098	-0.00199203
2015-11-24 00:00:00+00:00	-0.00904325	0.00264987
2015-11-25 00:00:00+00:00	-0.00617420	-0.00030891
2015-11-27 00:00:00+00:00	-0.00286889	0.00501270
2015-11-30 00:00:00+00:00	0.00010131	-0.00433862
2015-12-01 00:00:00+00:00	0.01692683	0.01502831
2015-12-02 00:00:00+00:00	-0.00447256	-0.01544806
2015-12-03 00:00:00+00:00	-0.02836674	-0.01572478
2015-12-04 00:00:00+00:00	0.01197660	0.02445235
2015-12-07 00:00:00+00:00	-0.00138396	-0.04208519
2015-12-08 00:00:00+00:00	-0.00627720	-0.03181317
2015-12-09 00:00:00+00:00	0.00220474	-0.00748954
2015-12-10 00:00:00+00:00	-0.00029673	0.01475919
2015-12-11 00:00:00+00:00	-0.01011228	-0.02978165
2015-12-14 00:00:00+00:00	0.00535594	-0.01499098
2015-12-15 00:00:00+00:00	0.01578682	0.03562574
2015-12-16 00:00:00+00:00	0.00860603	0.01075467
2015-12-17 00:00:00+00:00	-0.01196571	-0.01596035
2015-12-18 00:00:00+00:00	-0.01738362	-0.03784484
2015-12-21 00:00:00+00:00	0.01284185	0.00227072
2015-12-22 00:00:00+00:00	0.01496575	0.01455341
2015-12-23 00:00:00+00:00	0.01021896	0.01877295
2015-12-24 00:00:00+00:00	0.00136401	0.00397518
2015-12-28 00:00:00+00:00	-0.00641306	-0.00503256
2015-12-29 00:00:00+00:00	0.00723499	0.00617376
2015-12-30 00:00:00+00:00	-0.00292090	-0.01223479
2015-12-31 00:00:00+00:00	0.00117577	-0.00621188
2016-01-04 00:00:00+00:00	-0.00760365	-0.02161389
2016-01-05 00:00:00+00:00	0.02081954	-0.01085325

	Equity(490 [ZTS])
2011-01-07 00:00:00+00:00	0.00000000
2011-01-10 00:00:00+00:00	0.00000000
2011-01-11 00:00:00+00:00	0.00000000
2011-01-12 00:00:00+00:00	0.00000000
2011-01-13 00:00:00+00:00	0.00000000
2011-01-14 00:00:00+00:00	0.00000000
2011-01-18 00:00:00+00:00	0.00000000
2011-01-19 00:00:00+00:00	0.00000000

```
2011-01-20 00:00:00+00:00         0.00000000
2011-01-21 00:00:00+00:00         0.00000000
2011-01-24 00:00:00+00:00         0.00000000
2011-01-25 00:00:00+00:00         0.00000000
2011-01-26 00:00:00+00:00         0.00000000
2011-01-27 00:00:00+00:00         0.00000000
2011-01-28 00:00:00+00:00         0.00000000
2011-01-31 00:00:00+00:00         0.00000000
2011-02-01 00:00:00+00:00         0.00000000
2011-02-02 00:00:00+00:00         0.00000000
2011-02-03 00:00:00+00:00         0.00000000
2011-02-04 00:00:00+00:00         0.00000000
2011-02-07 00:00:00+00:00         0.00000000
2011-02-08 00:00:00+00:00         0.00000000
2011-02-09 00:00:00+00:00         0.00000000
2011-02-10 00:00:00+00:00         0.00000000
2011-02-11 00:00:00+00:00         0.00000000
2011-02-14 00:00:00+00:00         0.00000000
2011-02-15 00:00:00+00:00         0.00000000
2011-02-16 00:00:00+00:00         0.00000000
2011-02-17 00:00:00+00:00         0.00000000
2011-02-18 00:00:00+00:00         0.00000000
...                                      ...
2015-11-20 00:00:00+00:00         0.00894971
2015-11-23 00:00:00+00:00        -0.00760006
2015-11-24 00:00:00+00:00        -0.00065084
2015-11-25 00:00:00+00:00         0.00086836
2015-11-27 00:00:00+00:00         0.00234253
2015-11-30 00:00:00+00:00        -0.00807150
2015-12-01 00:00:00+00:00         0.00663191
2015-12-02 00:00:00+00:00        -0.01360986
2015-12-03 00:00:00+00:00        -0.02524442
2015-12-04 00:00:00+00:00         0.02788171
2015-12-07 00:00:00+00:00        -0.01184133
2015-12-08 00:00:00+00:00         0.00066573
2015-12-09 00:00:00+00:00        -0.01590047
2015-12-10 00:00:00+00:00         0.01969533
2015-12-11 00:00:00+00:00        -0.00585635
2015-12-14 00:00:00+00:00         0.01658331
2015-12-15 00:00:00+00:00         0.00815639
2015-12-16 00:00:00+00:00         0.00253774
2015-12-17 00:00:00+00:00        -0.00763722
2015-12-18 00:00:00+00:00        -0.00279062
2015-12-21 00:00:00+00:00         0.01589418
2015-12-22 00:00:00+00:00         0.00802720
2015-12-23 00:00:00+00:00         0.00544406
2015-12-24 00:00:00+00:00         0.00312135
2015-12-28 00:00:00+00:00        -0.00478388
```

```
2015-12-29 00:00:00+00:00         0.00899694
2015-12-30 00:00:00+00:00        -0.00145450
2015-12-31 00:00:00+00:00        -0.00705088
2016-01-04 00:00:00+00:00        -0.01356408
2016-01-05 00:00:00+00:00         0.01564723

[1256 rows x 490 columns]
```

2 Statistical Risk Model

It's time to build the risk model. You'll be creating a statistical risk model using PCA. So, the first thing is building the PCA model. ## Fit PCA Implement `fit_pca` to fit a PCA model to the returns data

```
In [9]: from sklearn.decomposition import PCA
```

```
def fit_pca(returns, num_factor_exposures, svd_solver):
    """
    Fit PCA model with returns.

    Parameters
    ----------
    returns : DataFrame
        Returns for each ticker and date
    num_factor_exposures : int
        Number of factors for PCA
    svd_solver: str
        The solver to use for the PCA model

    Returns
    -------
    pca : PCA
        Model fit to returns
    """
    #TODO: Implement function

    # Lesson 24: Risk Factor Models with PCA - Concept 18: PCA as a Factor Model Coding
    # create a function, fit_pca(returns, num_factor_exposures, svd_solver) that uses
    # Scikit-Learn's PCA() class to fit the returns dataframe with the given number of n
    # factor_exposures (Principal Components) and with the given svd_solver. The returns
    # is the pandas dataframe of returns given at the begining of the notebook. The num_
    # parameter is an integer representing the number of Principal Components you want t
    # PCA algorithm. The svd_solver parameter is a string that determines the type of so
    # to use in your PCA algorithm. To see the type of solvers that you can use, see the
    # documentation (http://scikit-learn.org/stable/modules/generated/sklearn.decomposit
    # The function must fit the returns and return the pca object.
```

```
    pca = PCA( n_components = num_factor_exposures,
               svd_solver = svd_solver )
    pca.fit(returns)

    return pca


project_tests.test_fit_pca(fit_pca)
```

```
Tests Passed
```

2.0.1 View Data

Let's see what the model looks like. First, we'll look at the PCA components.

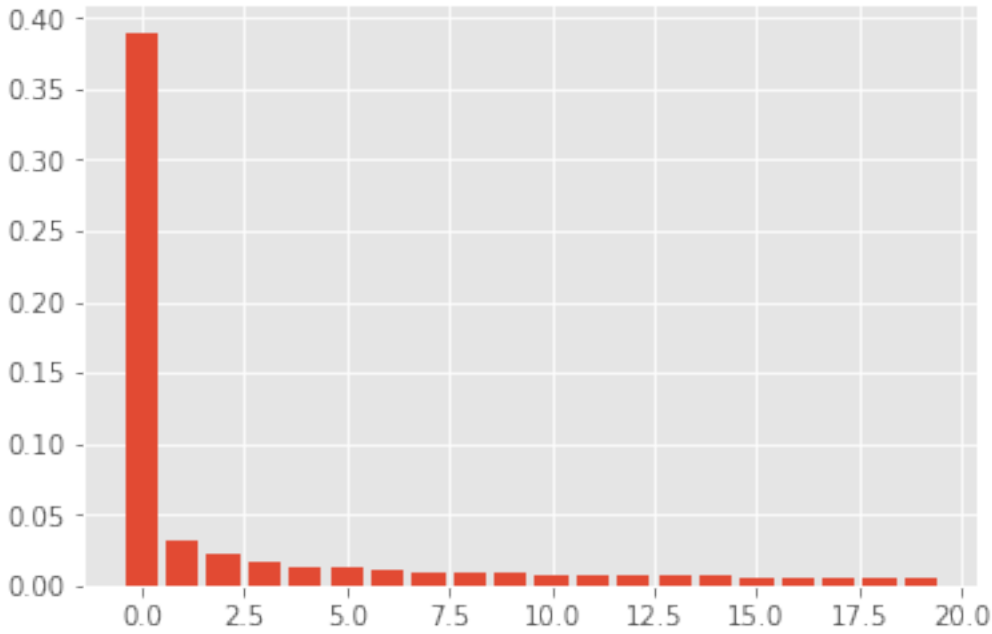
```
In [10]: num_factor_exposures = 20
         pca = fit_pca(five_year_returns, num_factor_exposures, 'full')

         pca.components_
```

```
Out[10]: array([[-0.04316847, -0.05874471, -0.03433256, ..., -0.03843904,
                 -0.06092493, -0.01367163],
                [ 0.01955111,  0.19637679,  0.03451503, ...,  0.01749339,
                 -0.01044197,  0.01892192],
                [-0.00993375,  0.07868756,  0.01133839, ..., -0.0157519 ,
                  0.01261759,  0.01867875],
                ...,
                [-0.01174265,  0.01398085,  0.05143999, ...,  0.04125323,
                  0.0035229 ,  0.03682367],
                [ 0.00526925, -0.04680674,  0.05716915, ...,  0.00671842,
                 -0.02193923,  0.00833979],
                [-0.00535269, -0.01599057,  0.08414961, ..., -0.01540844,
                  0.02188794,  0.01500221]])
```

Let's also look at the PCA's percent of variance explained by each factor

```
In [11]: plt.bar(np.arange(num_factor_exposures), pca.explained_variance_ratio_)
```

```
Out[11]: <Container object of 20 artists>
```



You will see that the first factor dominates. The precise definition of each factor in a latent model is unknown, however we can guess at the likely interpretation.

2.1 Factor Betas

Implement `factor_betas` to get the factor betas from the PCA model.

```
In [12]: def factor_betas(pca, factor_beta_indices, factor_beta_columns):
             """
             Get the factor betas from the PCA model.

             Parameters
             ----------
             pca : PCA
                 Model fit to returns
             factor_beta_indices : 1 dimensional Ndarray
                 Factor beta indices
             factor_beta_columns : 1 dimensional Ndarray
                 Factor beta columns

             Returns
             -------
             factor_betas : DataFrame
                 Factor betas
             """
             assert len(factor_beta_indices.shape) == 1
             assert len(factor_beta_columns.shape) == 1
```

```
    #TODO: Implement function

    # Lesson 24: Risk Factor Models with PCA - Concept 18: PCA as a Factor Model Coding
    #
    # write a function, factor_betas(pca, factor_beta_indices, factor_beta_columns) tha
    # factor exposures from Scikit-Learn's PCA() class. Remember the matrix of factor e
    # describes the coordintates of the Principal Components in the original basis. The
    # must be a Scikit-Learn's pca object, that has fit the model with the returns. In
    # must first run pca.fit(returns) before passing this parameter into the function.
    # notebook we created a function, fit_pca(), that will fit the pca model and return
    # The factor_beta_indices parameter must be a 1 dimensional ndarray containg the co
    # returns dataframe. The factor_beta_columns parameter must be a 1 dimensional ndar
    # spaced integers from 0 up to the number of principal components you used in your
    # For example, if you used 5 principal compoenents in your pca model, pca = PCA(n_c
    # factor_beta_columns = [0, 1, 2, 3, 4]. This function has to return a Pandas dataf
    # exposures, where the factor_beta_indices correspond to the indices of the datafra
    # correspond to the column names of the dataframe.
    df_factor_betas = pd.DataFrame( pca.components_.T,
                                    factor_beta_indices,
                                    factor_beta_columns )


    return df_factor_betas


project_tests.test_factor_betas(factor_betas)
```

```
Tests Passed
```

2.1.1 View Data

Let's view the factor betas from this model.

```
In [13]: risk_model = {}
         risk_model['factor_betas'] = factor_betas(pca, five_year_returns.columns.values, np.ara

         risk_model['factor_betas']
```

Out[13]:

	0	1	2	3	\
Equity(0 [A])	-0.04316847	0.01955111	-0.00993375	0.01054038	
Equity(1 [AAL])	-0.05874471	0.19637679	0.07868756	0.08209582	
Equity(2 [AAP])	-0.03433256	0.03451503	0.01133839	-0.02543666	
Equity(3 [AAPL])	-0.03409988	-0.00139319	0.03946700	-0.01721303	
Equity(4 [ABBV])	-0.01803099	0.02568151	0.00435183	-0.07078179	
Equity(5 [ABC])	-0.02890016	0.03259161	-0.00742074	-0.03355183	
Equity(6 [ABT])	-0.02905740	0.02977821	-0.02970871	-0.03574263	
Equity(7 [ACN])	-0.04337745	0.00256907	0.00413229	-0.00349265	

```
Equity(8 [ADBE])   -0.04730285  0.02661175  0.03057072 -0.02114690
Equity(9 [ADI])    -0.04712287 -0.00381150  0.05600847 -0.01553775
Equity(10 [ADM])   -0.04375945 -0.01130045 -0.03457005  0.00400541
Equity(11 [ADP])   -0.03648136  0.02528125 -0.01114832 -0.00940984
Equity(12 [ADS])   -0.04136654  0.01659887  0.01716323 -0.02418717
Equity(13 [ADSK])  -0.06028785  0.01995266  0.05164356  0.00105689
Equity(14 [AEE])   -0.02646901  0.02222316 -0.10714999 -0.03824488
Equity(15 [AEP])   -0.02263370  0.01880106 -0.10030310 -0.04210462
Equity(16 [AES])   -0.04557539 -0.01859287 -0.06960047 -0.02023102
Equity(17 [AET])   -0.04072498  0.02731997 -0.00507231 -0.02802199
Equity(18 [AFL])   -0.05336864  0.00134653 -0.02782496  0.06688998
Equity(19 [AGN])   -0.03534102  0.04465091  0.02264084 -0.09556088
Equity(20 [AIG])   -0.05982324  0.00588515 -0.01162873  0.06668318
Equity(21 [AIV])   -0.04111735  0.03100207 -0.10211708 -0.00919327
Equity(22 [AIZ])   -0.04150874  0.01695771 -0.03297298  0.04770347
Equity(23 [AJG])   -0.03351812  0.01723113 -0.02538602  0.01303842
Equity(24 [AKAM])  -0.05587884  0.00798596  0.06670064 -0.00705542
Equity(25 [ALB])   -0.05982022 -0.03657577  0.01798669  0.01363477
Equity(26 [ALGN])  -0.05959262  0.01420686  0.04030645 -0.00223610
Equity(27 [ALK])   -0.04887994  0.12134700  0.03971829  0.02356295
Equity(28 [ALL])   -0.03960459  0.01388579 -0.04298737  0.04705234
Equity(29 [ALLE])  -0.01215236  0.01485340  0.01783511 -0.02151478
...                      ...         ...         ...         ...
Equity(460 [VRSN]) -0.03899324  0.01109333  0.04065347 -0.01351021
Equity(461 [VRTX]) -0.04909379  0.09821506  0.07490354 -0.22874272
Equity(462 [VTR])  -0.03291326  0.03068907 -0.12174007 -0.03757317
Equity(463 [VZ])   -0.07033190  0.00068427 -0.01610414  0.05981359
Equity(464 [WAT])  -0.04787963  0.01976102  0.00630830 -0.01309650
Equity(465 [WBA])  -0.03065220  0.03421533 -0.01027997 -0.04006665
Equity(466 [WDC])  -0.05340806 -0.00776436  0.06117296 -0.01397300
Equity(467 [WEC])  -0.02279115  0.02557593 -0.10491696 -0.04691482
Equity(468 [WFC])  -0.05131308  0.01109305 -0.03096455  0.08514607
Equity(469 [WHR])  -0.05507142  0.03637282 -0.00100598  0.00590479
Equity(471 [WM])   -0.03151644  0.01496675 -0.03234348 -0.00111937
Equity(472 [WMB])  -0.05476156 -0.08924998 -0.02426238 -0.05723889
Equity(473 [WMT])  -0.01988671  0.03467415 -0.04017193 -0.00769646
Equity(474 [WRK])  -0.00563001 -0.00526226  0.00630657 -0.00994056
Equity(475 [WU])   -0.04059879  0.00365919  0.01271940  0.00231537
Equity(476 [WY])   -0.04860757  0.01225382 -0.04997087  0.00551805
Equity(477 [WYN])  -0.05535480  0.02642294  0.00304199 -0.00979668
Equity(478 [WYNN]) -0.06224023 -0.03777009  0.05699233 -0.04984462
Equity(479 [XEC])  -0.06269690 -0.17159838  0.01127251 -0.03690692
Equity(480 [XEL])  -0.02213358  0.02037290 -0.09965905 -0.04339570
Equity(481 [XL])   -0.04533940  0.01070557 -0.03511721  0.04642140
Equity(482 [XLNX]) -0.04210479 -0.00382104  0.05760794 -0.01871999
Equity(483 [XOM])  -0.03773468 -0.05378131 -0.03367517 -0.01036467
Equity(484 [XRAY]) -0.04417162  0.01778874 -0.00062230  0.00814409
Equity(485 [XRX])  -0.05418096 -0.00344402  0.01002127  0.02970052
```

```
Equity(486 [XYL])  -0.02818794 -0.01716654  0.03265037 -0.01947739
Equity(487 [YUM])  -0.03630261  0.02726148  0.00226076 -0.02614444
Equity(488 [ZBH])  -0.03843904  0.01749339 -0.01575190 -0.01540756
Equity(489 [ZION]) -0.06092493 -0.01044197  0.01261759  0.13419161
Equity(490 [ZTS])  -0.01367163  0.01892192  0.01867875 -0.04878703

                            4           5           6           7   \
Equity(0 [A])      -0.01819821  0.01074517  0.00112915  0.03973914
Equity(1 [AAL])     0.34847826 -0.13808246  0.07129285  0.10524788
Equity(2 [AAP])    -0.00817211 -0.01318319 -0.06095238  0.00654915
Equity(3 [AAPL])   -0.03046983 -0.01757067  0.02325117  0.01142987
Equity(4 [ABBV])    0.01319937  0.05427710 -0.01567842  0.04046172
Equity(5 [ABC])    -0.01152149  0.02648421  0.01084965 -0.00570393
Equity(6 [ABT])    -0.01157351  0.06020073 -0.02004042  0.04098522
Equity(7 [ACN])    -0.05430743  0.00537434  0.00277996  0.03043220
Equity(8 [ADBE])   -0.04838794 -0.00708698  0.00743385  0.00747095
Equity(9 [ADI])    -0.06946243 -0.00560418  0.10070366  0.06307694
Equity(10 [ADM])   -0.00645333  0.01746845 -0.00146122  0.04177642
Equity(11 [ADP])   -0.03357614  0.02887659 -0.00509280  0.04466799
Equity(12 [ADS])   -0.00389740  0.00098181 -0.02299563  0.01316338
Equity(13 [ADSK])  -0.06889175 -0.04893180  0.04706144 -0.02746946
Equity(14 [AEE])   -0.00157895 -0.02310383  0.02412315  0.04419314
Equity(15 [AEP])    0.00205558 -0.03150526  0.02496444  0.05473617
Equity(16 [AES])    0.01303429 -0.01748403  0.02894033  0.03053573
Equity(17 [AET])   -0.00180323  0.06383735  0.00044765 -0.03716524
Equity(18 [AFL])   -0.01355109  0.04111821 -0.00401011 -0.01388700
Equity(19 [AGN])    0.02867567  0.06515425 -0.02264216 -0.01928860
Equity(20 [AIG])    0.01385338  0.04010201 -0.01874280 -0.02394864
Equity(21 [AIV])    0.01055402 -0.04739093  0.05244727 -0.09495931
Equity(22 [AIZ])   -0.00003273  0.04220872 -0.00295921  0.01717020
Equity(23 [AJG])   -0.00670008  0.02117990 -0.01015869  0.00117300
Equity(24 [AKAM])  -0.05149731 -0.04837770  0.02745032 -0.00620225
Equity(25 [ALB])   -0.01737160 -0.03079886  0.04201500  0.00605395
Equity(26 [ALGN])   0.00381377  0.03559561  0.04027152 -0.09389473
Equity(27 [ALK])    0.12648496 -0.05703822  0.02168427  0.06427147
Equity(28 [ALL])   -0.00073028  0.03487833 -0.01156382  0.00877075
Equity(29 [ALLE])   0.00049741  0.02208048 -0.01396758  0.04557020
...                      ...         ...         ...         ...
Equity(460 [VRSN]) -0.03906872  0.00844214  0.01232426 -0.02031680
Equity(461 [VRTX])  0.18286011  0.29795662  0.16783749 -0.08588784
Equity(462 [VTR])  -0.00091457 -0.05384826  0.03088016 -0.06663125
Equity(463 [VZ])   -0.01922444  0.03298870 -0.00089302 -0.00205798
Equity(464 [WAT])  -0.02786813  0.02969891  0.01135497 -0.01289454
Equity(465 [WBA])  -0.01725655  0.02037446 -0.00923922  0.04976024
Equity(466 [WDC])  -0.02898379 -0.05151527  0.10653647  0.00360483
Equity(467 [WEC])  -0.00109145 -0.02887550  0.01886320  0.05105952
Equity(468 [WFC])   0.00399898  0.06168940 -0.01917540 -0.00980213
Equity(469 [WHR])   0.01092658 -0.06423664 -0.05592381  0.02535313
```

```
Equity(471 [WM])   -0.02960532  0.00379175 -0.00185568  0.01331670
Equity(472 [WMB])   0.07886307 -0.01255032 -0.03519116  0.02300738
Equity(473 [WMT])  -0.01460066  0.00726635 -0.02275936  0.03829212
Equity(474 [WRK])   0.00615504  0.01085219  0.00188007  0.01706454
Equity(475 [WU])   -0.01726731  0.03143078  0.02344129  0.01431019
Equity(476 [WY])   -0.00278578 -0.03035081  0.01706471 -0.04454320
Equity(477 [WYN])  -0.00616717 -0.02917053 -0.01685646 -0.03459347
Equity(478 [WYNN])  0.00328186 -0.05450135 -0.01461477 -0.13651307
Equity(479 [XEC])   0.07210881  0.04237735 -0.01733096 -0.00894589
Equity(480 [XEL])  -0.00356988 -0.02492272  0.01491957  0.05105363
Equity(481 [XL])   -0.00583933  0.01175012  0.01269465 -0.02088638
Equity(482 [XLNX]) -0.06972723 -0.01255952  0.09049018  0.05367295
Equity(483 [XOM])  -0.00395082  0.02952766 -0.00565258  0.04906130
Equity(484 [XRAY]) -0.02933804  0.01859296  0.01513543 -0.00291478
Equity(485 [XRX])  -0.04632619  0.01414187  0.01544957  0.03335353
Equity(486 [XYL])  -0.00284445  0.00870998 -0.01888604  0.06659425
Equity(487 [YUM])  -0.01418528  0.00132929 -0.04156624  0.00017706
Equity(488 [ZBH])  -0.00162086  0.04604255  0.00107619 -0.00762158
Equity(489 [ZION])  0.02396471  0.09232022 -0.04477488 -0.03030878
Equity(490 [ZTS])   0.01263697  0.04831930 -0.00205544  0.01613385

                            8           9           10           11  \
Equity(0 [A])      -0.01380519  0.01273651 -0.02384028 -0.00141663
Equity(1 [AAL])    -0.04588957 -0.08547793  0.00328328  0.10534284
Equity(2 [AAP])    -0.03265404 -0.01351522  0.02896685  0.03836520
Equity(3 [AAPL])   -0.02656849 -0.00771904  0.02686350  0.00731877
Equity(4 [ABBV])   -0.01245487 -0.03515086 -0.05132433 -0.04041614
Equity(5 [ABC])     0.01354800 -0.02967931 -0.03161765  0.01715152
Equity(6 [ABT])    -0.01803987 -0.00620785 -0.03157790 -0.02308041
Equity(7 [ACN])    -0.01880168 -0.00178336 -0.03540357 -0.01093170
Equity(8 [ADBE])    0.01487098 -0.00153422 -0.01238383 -0.00667442
Equity(9 [ADI])     0.00160769  0.01912993  0.01101680  0.00348733
Equity(10 [ADM])   -0.00478644 -0.01859623  0.00422432 -0.00952513
Equity(11 [ADP])   -0.00676480  0.00335015 -0.00493401  0.00194010
Equity(12 [ADS])   -0.02790599  0.00654660  0.00628604 -0.00342924
Equity(13 [ADSK])   0.00290438  0.00534281 -0.01150281 -0.00105789
Equity(14 [AEE])    0.00041473 -0.02597657  0.02325386 -0.05456489
Equity(15 [AEP])    0.00166554 -0.02261936  0.01766823 -0.04791054
Equity(16 [AES])   -0.01228381 -0.02623395  0.00383933 -0.05881947
Equity(17 [AET])    0.00999656 -0.09646860 -0.04571407  0.04559328
Equity(18 [AFL])    0.01362724  0.00343990 -0.00993833 -0.00945988
Equity(19 [AGN])   -0.02379115 -0.02578767 -0.02640179 -0.00734949
Equity(20 [AIG])    0.01457678  0.02061950 -0.00588748 -0.01886738
Equity(21 [AIV])    0.04963087  0.00394508  0.02486556  0.02540802
Equity(22 [AIZ])    0.02192818 -0.01979049  0.00845285 -0.00209358
Equity(23 [AJG])    0.00768045  0.00434263 -0.00824876  0.01520847
Equity(24 [AKAM])   0.02668695 -0.01154353  0.00107161 -0.06366032
Equity(25 [ALB])   -0.02047597  0.03736635 -0.00136191  0.01865916
```

```
Equity(26 [ALGN])   0.03501042  0.00979674 -0.07400799  0.02204550
Equity(27 [ALK])   -0.01679148 -0.02374091 -0.00059277  0.06395819
Equity(28 [ALL])   -0.00074882 -0.00128949  0.01279480 -0.00687101
Equity(29 [ALLE])  -0.01575920  0.00225117 -0.01540340 -0.02608136
...                       ...         ...         ...         ...
Equity(460 [VRSN]) -0.01427350 -0.00833205 -0.02485455  0.02115889
Equity(461 [VRTX])  0.17241447  0.26880311  0.58246071 -0.03464001
Equity(462 [VTR])   0.04680683  0.00814737 -0.00367371  0.02294498
Equity(463 [VZ])    0.03346385 -0.00820052  0.01313467 -0.01333200
Equity(464 [WAT])   0.02281688  0.00205729 -0.05584809  0.02544186
Equity(465 [WBA])  -0.02415684 -0.02906100 -0.01704871 -0.00978625
Equity(466 [WDC])  -0.00177534 -0.01754129  0.03043852 -0.00839301
Equity(467 [WEC])   0.01033805 -0.02583748  0.02240632 -0.04433949
Equity(468 [WFC])   0.02012808  0.00922159  0.02755224 -0.01813056
Equity(469 [WHR])  -0.04216377  0.13444741 -0.01648804  0.01561092
Equity(471 [WM])   -0.00239896 -0.00938471  0.00277936  0.00920572
Equity(472 [WMB])  -0.03160335 -0.02914851  0.00854960  0.01996384
Equity(473 [WMT])  -0.01129245 -0.00761002  0.00867345  0.00383922
Equity(474 [WRK])  -0.00685762 -0.00781146  0.00359568 -0.02948648
Equity(475 [WU])   -0.02394147 -0.00790867 -0.02335012 -0.00977388
Equity(476 [WY])    0.02067441  0.04950772 -0.02155464 -0.01867393
Equity(477 [WYN])  -0.04851210 -0.00714578  0.02188880  0.02067000
Equity(478 [WYNN]) -0.10364775 -0.13173348  0.08154700 -0.21134975
Equity(479 [XEC])  -0.00116263 -0.04083135  0.00912637  0.02183445
Equity(480 [XEL])  -0.00024236 -0.02451330  0.01835319 -0.05349810
Equity(481 [XL])    0.01106751 -0.00003951  0.00649962  0.00959532
Equity(482 [XLNX])  0.00001376  0.00960728  0.01455370  0.00163722
Equity(483 [XOM])   0.00089804 -0.00311029 -0.00739458 -0.01164590
Equity(484 [XRAY]) -0.00638183 -0.00958277 -0.01879890  0.00101476
Equity(485 [XRX])  -0.00134738 -0.03200626 -0.00744424 -0.01931881
Equity(486 [XYL])  -0.02409194  0.03602542 -0.02482881 -0.03921085
Equity(487 [YUM])  -0.03049746 -0.02788495  0.01280995  0.00298781
Equity(488 [ZBH])   0.00942745 -0.01275463 -0.06637911 -0.01112025
Equity(489 [ZION])  0.03194794 -0.01095035  0.04091415 -0.01621729
Equity(490 [ZTS])  -0.01918963 -0.03072014 -0.04031418 -0.03085290

                           12          13          14          15  \
Equity(0 [A])       0.02099338  0.03460997 -0.03048936  0.03360635
Equity(1 [AAL])     0.06721603 -0.04405955 -0.02231617  0.01726309
Equity(2 [AAP])    -0.04960451 -0.00524576 -0.02196994  0.02976718
Equity(3 [AAPL])    0.00481832  0.01288623  0.05256513 -0.07344470
Equity(4 [ABBV])   -0.05120320 -0.01858166 -0.01126857 -0.04200714
Equity(5 [ABC])    -0.00304998  0.02635564  0.00787900  0.00833106
Equity(6 [ABT])    -0.01436789 -0.00054254 -0.01932887  0.01428819
Equity(7 [ACN])     0.02611241 -0.01233115  0.00322097  0.01770011
Equity(8 [ADBE])    0.03500718 -0.04336579  0.01060255 -0.00637875
Equity(9 [ADI])    -0.05465749 -0.04223802 -0.00014275 -0.04843166
Equity(10 [ADM])   -0.01336835  0.01753074  0.00993158  0.02405739
```

Equity(11 [ADP])	-0.01057350	-0.00616905	-0.00351046	-0.00218630
Equity(12 [ADS])	0.01596979	-0.02290249	0.01812681	0.00269984
Equity(13 [ADSK])	0.04046916	-0.03266419	0.02070996	0.02100687
Equity(14 [AEE])	0.00729924	-0.00884432	0.02876494	0.02575176
Equity(15 [AEP])	-0.01334963	-0.00584932	0.03513664	0.02664964
Equity(16 [AES])	-0.01427757	0.01071751	0.04800697	0.00823278
Equity(17 [AET])	-0.08527159	0.06484179	-0.07164819	0.00852602
Equity(18 [AFL])	0.01378441	-0.00676370	0.00047075	0.00042919
Equity(19 [AGN])	-0.01375720	0.01729325	0.00910558	0.01765223
Equity(20 [AIG])	-0.00536267	-0.02808023	0.03227634	-0.01100650
Equity(21 [AIV])	0.02094801	-0.04206507	-0.02048654	-0.03732772
Equity(22 [AIZ])	-0.02121338	-0.01017076	0.02874684	0.01121282
Equity(23 [AJG])	-0.00142810	-0.00802982	-0.00533986	-0.00140466
Equity(24 [AKAM])	-0.07429360	0.00240076	0.12416841	0.13836518
Equity(25 [ALB])	0.04131905	0.09156602	-0.06656052	-0.01740400
Equity(26 [ALGN])	0.10784517	0.07096981	-0.05965948	-0.06617279
Equity(27 [ALK])	0.00033085	0.00597074	0.01458408	0.02170190
Equity(28 [ALL])	-0.00986285	-0.00905731	0.02499562	-0.00494904
Equity(29 [ALLE])	-0.00635063	-0.04124458	-0.00784737	-0.01976681
...	...	...	...	...
Equity(460 [VRSN])	0.00062521	0.01354571	0.02242982	0.03594197
Equity(461 [VRTX])	-0.12627708	0.36184696	-0.14161962	-0.10440960
Equity(462 [VTR])	0.02497163	-0.03310961	-0.01353316	-0.02038055
Equity(463 [VZ])	0.00415716	-0.00898788	0.00645221	-0.01738755
Equity(464 [WAT])	0.02317906	0.01111012	-0.03735916	0.03053670
Equity(465 [WBA])	-0.02967145	-0.00855083	-0.02413786	0.01716925
Equity(466 [WDC])	-0.11248908	0.02938310	0.13499041	0.17141412
Equity(467 [WEC])	0.00086058	-0.01721494	0.02251708	0.01433085
Equity(468 [WFC])	-0.00880242	-0.02231278	0.02429464	0.00372331
Equity(469 [WHR])	-0.05450337	0.04108206	0.04115321	0.02808061
Equity(471 [WM])	-0.00692979	0.03223594	-0.01134834	0.03628231
Equity(472 [WMB])	-0.01039337	-0.00287563	0.03826935	-0.02475861
Equity(473 [WMT])	-0.04340883	0.02467536	0.01323727	0.01194552
Equity(474 [WRK])	-0.02071811	0.00905441	0.00186650	-0.01865369
Equity(475 [WU])	-0.00331322	-0.02121476	0.00574640	-0.03553201
Equity(476 [WY])	-0.00268823	0.02518978	-0.01532718	-0.02625075
Equity(477 [WYN])	0.01051755	0.02073259	0.01106532	0.01470477
Equity(478 [WYNN])	0.05793940	0.06955993	-0.05215021	0.00468932
Equity(479 [XEC])	-0.00217537	-0.10441731	-0.05669005	0.00593931
Equity(480 [XEL])	-0.00097559	-0.00596671	0.02197929	0.01863163
Equity(481 [XL])	0.00151969	-0.00052693	0.00744188	0.01978538
Equity(482 [XLNX])	-0.03587944	-0.04241793	0.00144974	-0.03148143
Equity(483 [XOM])	-0.01051455	0.01413654	0.00286959	0.00192552
Equity(484 [XRAY])	0.01167483	0.02288506	-0.02825392	0.01102642
Equity(485 [XRX])	-0.03324697	0.01915283	-0.01067988	-0.01247793
Equity(486 [XYL])	-0.00964275	-0.04118213	-0.05878742	-0.02300320
Equity(487 [YUM])	-0.01235304	0.00926070	0.00035906	-0.00496092
Equity(488 [ZBH])	-0.02675098	0.01827896	-0.04768582	0.01395948

```
Equity(489 [ZION]) -0.01158269 -0.03556539  0.00554836 -0.00341750
Equity(490 [ZTS])  -0.05612824 -0.01541907  0.00108249 -0.02396138

                            16          17          18          19
Equity(0 [A])      -0.01142920 -0.01174265  0.00526925 -0.00535269
Equity(1 [AAL])    -0.03310836  0.01398085 -0.04680674 -0.01599057
Equity(2 [AAP])    -0.01163585  0.05143999  0.05716915  0.08414961
Equity(3 [AAPL])   -0.03179158  0.09079374 -0.01118851  0.04291373
Equity(4 [ABBV])    0.01588559  0.04598554  0.01599288  0.06587978
Equity(5 [ABC])    -0.01834622 -0.01391370  0.01062042 -0.02739565
Equity(6 [ABT])    -0.03938064  0.01071208  0.01712006  0.00210689
Equity(7 [ACN])    -0.00285123 -0.01235874 -0.01400935 -0.03855653
Equity(8 [ADBE])    0.02127339 -0.03638845  0.00126811 -0.04844555
Equity(9 [ADI])     0.00374282  0.04583322  0.01483456  0.00768623
Equity(10 [ADM])   -0.02009143 -0.00246866  0.00264238 -0.00851815
Equity(11 [ADP])   -0.00363522  0.00584571  0.00578868 -0.02465380
Equity(12 [ADS])   -0.01166061 -0.02387829 -0.01844799  0.02639087
Equity(13 [ADSK])   0.05625388 -0.06442852 -0.03374250 -0.02718282
Equity(14 [AEE])    0.03531642 -0.00801202 -0.03297087 -0.03074790
Equity(15 [AEP])    0.03949487  0.00571290 -0.01621889 -0.01421124
Equity(16 [AES])    0.00968720 -0.02229136 -0.05731240 -0.01503171
Equity(17 [AET])    0.01958565  0.00069996  0.00650320 -0.05091908
Equity(18 [AFL])    0.00010718  0.00397769  0.01677661 -0.03209361
Equity(19 [AGN])   -0.02289392  0.02583835 -0.02092126  0.01964563
Equity(20 [AIG])   -0.00994737 -0.04884961 -0.01447059 -0.00092722
Equity(21 [AIV])   -0.01518008  0.02499635  0.04526409  0.06168561
Equity(22 [AIZ])    0.00889890 -0.01278457  0.00035505  0.00788631
Equity(23 [AJG])   -0.00386327 -0.01466289 -0.00523534  0.01165450
Equity(24 [AKAM])   0.00667736  0.00052245 -0.00203434  0.04370206
Equity(25 [ALB])   -0.04603229 -0.02452548 -0.02975526  0.05708918
Equity(26 [ALGN])   0.04902407  0.00156817 -0.03738565 -0.00223241
Equity(27 [ALK])    0.04257028  0.00789058  0.04963085 -0.04169300
Equity(28 [ALL])   -0.00115539  0.00082421  0.00224048 -0.00639780
Equity(29 [ALLE])  -0.00865976  0.03592991  0.00767178  0.03158662
...                       ...         ...         ...         ...
Equity(460 [VRSN]) -0.00752310 -0.00611545 -0.02595021 -0.00005537
Equity(461 [VRTX])  0.15669116  0.00258548  0.05374391 -0.10088761
Equity(462 [VTR])  -0.02035280 -0.00581734  0.04174183  0.02905358
Equity(463 [VZ])    0.00335631 -0.03321116 -0.03424556 -0.02031272
Equity(464 [WAT])  -0.01161567  0.05062677 -0.01607733 -0.02896756
Equity(465 [WBA])   0.02913337  0.03131836  0.01484323  0.00683342
Equity(466 [WDC])   0.11221658 -0.22112989 -0.05340130  0.27231589
Equity(467 [WEC])   0.04781420 -0.01020607 -0.01687023 -0.01798607
Equity(468 [WFC])  -0.00454128  0.00335586 -0.02606330  0.01015222
Equity(469 [WHR])   0.04912976  0.02732405  0.01817701  0.01086811
Equity(471 [WM])    0.01820702 -0.01988943  0.02403495  0.01042652
Equity(472 [WMB])  -0.02989245 -0.01712986 -0.10290158 -0.01224658
Equity(473 [WMT])  -0.02497356  0.00351902  0.00777862  0.01076198
```

```
Equity(474 [WRK])  -0.01239063  0.02357001 -0.02087232  0.04046773
Equity(475 [WU])   -0.00661356 -0.03045924  0.00995369 -0.04708063
Equity(476 [WY])   -0.02418712  0.00957536  0.01679332 -0.00412955
Equity(477 [WYN])  -0.00226587 -0.02256858 -0.03784605 -0.01748119
Equity(478 [WYNN]) -0.04338772  0.14131780 -0.02504257  0.02417878
Equity(479 [XEC])   0.06575714 -0.03770747  0.09486709 -0.06387098
Equity(480 [XEL])   0.04664665 -0.00826953 -0.01791475 -0.02072648
Equity(481 [XL])   -0.00164444  0.00315162  0.00519293 -0.03064259
Equity(482 [XLNX])  0.03558220  0.01661543  0.01022713 -0.00396583
Equity(483 [XOM])  -0.00324646  0.00012369  0.01694194  0.01003126
Equity(484 [XRAY])  0.01849776  0.00975355  0.00668087 -0.04636686
Equity(485 [XRX])   0.00098390 -0.04865041  0.01743092  0.00666409
Equity(486 [XYL])   0.00625647  0.04733302 -0.00256510  0.04937012
Equity(487 [YUM])  -0.01453755  0.01909012 -0.01126627 -0.00177409
Equity(488 [ZBH])   0.01018115  0.04125323  0.00671842 -0.01540844
Equity(489 [ZION])  0.00706111  0.00352290 -0.02193923  0.02188794
Equity(490 [ZTS])  -0.01026795  0.03682367  0.00833979  0.01500221

[490 rows x 20 columns]
```

2.2 Factor Returns

Implement `factor_returns` to get the factor returns from the PCA model using the returns data.

```
In [14]: def factor_returns(pca, returns, factor_return_indices, factor_return_columns):
             """
             Get the factor returns from the PCA model.

             Parameters
             ----------
             pca : PCA
                 Model fit to returns
             returns : DataFrame
                 Returns for each ticker and date
             factor_return_indices : 1 dimensional Ndarray
                 Factor return indices
             factor_return_columns : 1 dimensional Ndarray
                 Factor return columns

             Returns
             -------
             factor_returns : DataFrame
                 Factor returns
             """
             assert len(factor_return_indices.shape) == 1
             assert len(factor_return_columns.shape) == 1

             #TODO: Implement function
```

```
            # Lesson 24: Risk Factor Models with PCA - Concept 18: PCA as a Factor Model Coding
            #
            # write a function, factor_returns(pca, returns, factor_return_indices, factor_retu
            # that calculates the factor returns from Scikit-Learn's PCA() class. Remember the
            #  , represents the returns written in the new basis. The pca parameter must be a S
            # pca object, that has fit the model with the returns. In other words, you must fir
            # before passing this parameter into the function. Earlier in this notebook we crea
            # that will fit the pca model and return the pcaobject. The returns parameter is th
            # returns given at the begining of the notebook. The factor_return_indices paramete
            # ndarray containing the trading dates (Pandas DatetimeIndex) in the returns datafr
            # parameter must be a 1 dimensional ndarray containing evenly spaced integers from
            # components you used in your pca model minus one. For example, if you used 5 princ
            # pca = PCA(n_components = 5), then factor_beta_columns = [0, 1, 2, 3, 4]. This fun
            # dataframe with the factor returns, where the factor_return_indices correspond to
            # factor_return_columns correspond to the column names of the dataframe.
            df_factor_returns = pd.DataFrame(
                                                # .trasnform(X): Apply dimensionality reduction t
                                                # X is projected on the first principal component
                                                # http://scikit-learn.org/stable/modules/generate
                                                pca.transform(returns),
                                                factor_return_indices,
                                                factor_return_columns )

            return df_factor_returns


        project_tests.test_factor_returns(factor_returns)
```

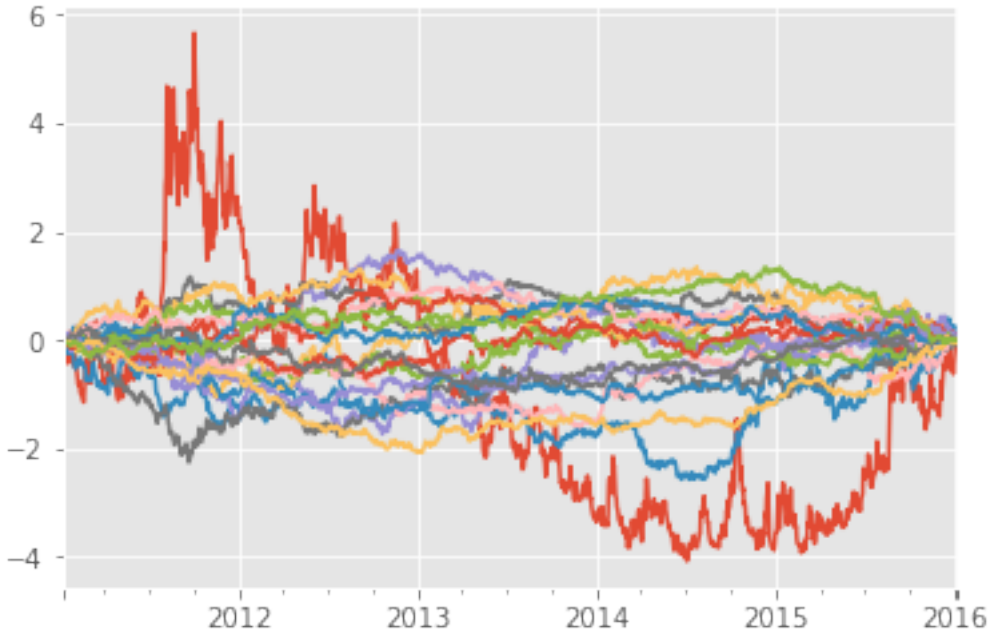
```
Tests Passed
```

2.2.1 View Data

Let's see what these factor returns looks like over time.

```
In [15]: risk_model['factor_returns'] = factor_returns(
             pca,
             five_year_returns,
             five_year_returns.index,
             np.arange(num_factor_exposures))

         risk_model['factor_returns'].cumsum().plot(legend=None)
```

```
Out[15]: <matplotlib.axes._subplots.AxesSubplot at 0x7f3daf204198>
```



2.3 Factor Covariance Matrix

Implement `factor_cov_matrix` to get the factor covariance matrix.

DE - NOTES To calculate the annualized factor covariance matrix, $\mathbf{F}$, we use the following equation:

$$\mathbf{F} = \frac{1}{N-1}\mathbf{f}\mathbf{f}^T$$

where, N is the number of elements in $\mathbf{f}$. Recall that the factor covariance matrix, $\mathbf{F}$, is a diagonal matrix.

With this in mind, create a function, `factor_cov_matrix(factor_returns, ann_factor)` that calculates the annualized factor covariance matrix from the factor returns $\mathbf{f}$. The `factor_returns` parameter is the output of the `factor_returns()` function created above and the `ann_factor` parameter is an integer representing the annualization factor. The function must return a diagonal numpy ndarray

HINT : You can calculate the factor covariance matrix $\mathbf{F}$ very easily using Numpy's `.var` method. The $\frac{1}{N-1}$ factor can be taken into account using the `ddof` keyword.

```
In [16]: def factor_cov_matrix(factor_returns, ann_factor):
             """
             Get the factor covariance matrix

             Parameters
             ----------
             factor_returns : DataFrame
                 Factor returns
```

```
        ann_factor : int
            Annualization factor

        Returns
        -------
        factor_cov_matrix : DataFrame
            Factor covariance matrix
        """

        #TODO: Implement function

        # Lesson 24: Risk Factor Models with PCA - Concept 18: PCA as a Factor Model Coding
        #
        # create a function, factor_cov_matrix(factor_returns, ann_factor) that calculates
        # covariance matrix from the factor returns   . The factor_returns parameter is the
        # function created above and the ann_factor parameter is an integer representing th
        # function must return a diagonal numpy ndarray
        df_factor_cov_matrix = np.diag( # https://docs.scipy.org/doc/numpy-1.15.1/reference
                                        factor_returns.var( axis = 0,
                                                            ddof = 1 ) * ann_factor )

    #     # DEBUG
    #     #
    #     temp_a = factor_returns.var( axis = 0,
    #                                  ddof = 1 ) * ann_factor

    #     print('DEBUG - temp_a: {}'.format(temp_a))
    #     print('DEBUG - df_factor_cov_matrix: {}'.format(df_factor_cov_matrix))

        return df_factor_cov_matrix


    project_tests.test_factor_cov_matrix(factor_cov_matrix)
```

```
Tests Passed
```

2.3.1 View Data

```
In [17]: ann_factor = 252
         risk_model['factor_cov_matrix'] = factor_cov_matrix(risk_model['factor_returns'], ann_f

         risk_model['factor_cov_matrix']
```

```
Out[17]: array([[ 14.01830425,   0.        ,   0.        ,   0.        ,
                   0.        ,   0.        ,   0.        ,   0.        ,
                   0.        ,   0.        ,   0.        ,   0.        ,
                   0.        ,   0.        ,   0.        ,   0.        ,
```

```
   0.        ,   0.        ,   0.        ,   0.        ],
[  0.        ,   1.10591127,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ],
[  0.        ,   0.        ,   0.77099145,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ],
[  0.        ,   0.        ,   0.        ,   0.61798821,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ],
[  0.        ,   0.        ,   0.        ,   0.        ,
   0.47589087,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ],
[  0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.43653315,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ],
[  0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.3873247 ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ],
[  0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.34930223,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ],
[  0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.34350302,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ],
[  0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.31674219,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ],
[  0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
```

```
   0.        ,   0.        ,   0.28186803,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ],
[  0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.2762745 ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ],
[  0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.26857691,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ],
[  0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.24981278,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ],
[  0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.23329965,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ],
[  0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.21393011,
   0.        ,   0.        ,   0.        ,   0.        ],
[  0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.20845473,   0.        ,   0.        ,   0.        ],
[  0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.19480492,   0.        ,   0.        ],
[  0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.19126517,   0.        ],
[  0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.        ,
   0.        ,   0.        ,   0.        ,   0.18725609]])
```

2.4 Idiosyncratic Variance Matrix

Implement `idiosyncratic_var_matrix` to get the idiosyncratic variance matrix.

DE - NOTES Let's review how we can calculate the Idiosyncratic Risk Matrix **S**. We know that:

$$\mathbf{s} = \mathbf{r} - \mathbf{Bf}$$

We refer to **s** as the residuals. To calculate the idiosyncratic or specific risk matrix **S**, we have to calculate the covariance matrix of the residuals, **s**, and set the off-diagonal elements to zero.

With this in mind, in the code below cerate a function, `idiosyncratic_var_matrix(returns, factor_returns, factor_betas, ann_factor)` that calclates the **annualized** Idiosyncratic Risk Matrix. The `returns` parameter is the pandas dataframe of returns given at the begining of the notebook. The `factor_returns` parameter is the output of the `factor_returns()` function created above. Similarly, the `factor_betas` parameter is the output of the `factor_betas()` function created above. The `ann_factor` parameter is an integer representing the annualization factor.

Remember that if the `returns` time series are daily returns, then when we calculate the Idiosyncratic Risk Matrix we will get values on a daily basis. We can annualize these values simply by multiplying the whole Idiosyncratic Risk Matrix by an annualization factor of 252. Remember we don't need the square root of the factor because our numbers here are variances not standard deviations.

The function must return a pandas dataframe with the annualized Idiosyncratic Risk Matrix containing the covariance of the residuals in its main diagonal and with all the off-diagonal elements set to zero.

```
In [18]: def idiosyncratic_var_matrix(returns, factor_returns, factor_betas, ann_factor):
             """
             Get the idiosyncratic variance matrix

             Parameters
             ----------
             returns : DataFrame
                 Returns for each ticker and date
             factor_returns : DataFrame
                 Factor returns
             factor_betas : DataFrame
                 Factor betas
             ann_factor : int
                 Annualization factor

             Returns
             -------
             idiosyncratic_var_matrix : DataFrame
                 Idiosyncratic variance matrix
             """

             #TODO: Implement function

             # Lesson 24: Risk Factor Models with PCA - Concept 18: PCA as a Factor Model Coding
```

```
    #
    # the code below cerate a function, idiosyncratic_var_matrix(returns, factor_return
    # that calclates the annualized Idiosyncratic Risk Matrix. The returns parameter is
    # given at the begining of the notebook. The factor_returns parameter is the output
    # created above. Similarly, the factor_betas parameter is the output of the factor_
    # The ann_factor parameter is an integer representing the annualization factor.
    # Remember that if the returns time series are daily returns, then when we calculat
    # will get values on a daily basis. We can annualize these values simply by multipl
    # Matrix by an annualization factor of 252. Remember we don't need the square root
    # here are variances not standard deviations.
    # The function must return a pandas dataframe with the annualized Idiosyncratic Ris
    # of the residuals in its main diagonal and with all the off-diagonal elements set
    common_returns_ = pd.DataFrame( np.dot( factor_returns,
                                            factor_betas.T ),
                                    returns.index,
                                    returns.columns )

    residuals_ = (returns - common_returns_)

    df_idiosyncratic_var_matrix = pd.DataFrame( # NOTE: This is where we multiply by 25
                                                #       to make make daily returns into
                                                np.diag( np.var(residuals_) ) * ann_fac
                                                returns.columns,
                                                returns.columns )

    return df_idiosyncratic_var_matrix


project_tests.test_idiosyncratic_var_matrix(idiosyncratic_var_matrix)
```

```
Tests Passed
```

2.4.1 View Data

```
In [19]: risk_model['idiosyncratic_var_matrix'] = idiosyncratic_var_matrix(five_year_returns, ri

         risk_model['idiosyncratic_var_matrix']
```

Out[19]:

	Equity(0 [A])	Equity(1 [AAL])	Equity(2 [AAP])	\
Equity(0 [A])	0.02272535	0.00000000	0.00000000	
Equity(1 [AAL])	0.00000000	0.05190083	0.00000000	
Equity(2 [AAP])	0.00000000	0.00000000	0.05431181	
Equity(3 [AAPL])	0.00000000	0.00000000	0.00000000	
Equity(4 [ABBV])	0.00000000	0.00000000	0.00000000	
Equity(5 [ABC])	0.00000000	0.00000000	0.00000000	
Equity(6 [ABT])	0.00000000	0.00000000	0.00000000	
Equity(7 [ACN])	0.00000000	0.00000000	0.00000000	

Equity(8 [ADBE])	0.00000000	0.00000000	0.00000000
Equity(9 [ADI])	0.00000000	0.00000000	0.00000000
Equity(10 [ADM])	0.00000000	0.00000000	0.00000000
Equity(11 [ADP])	0.00000000	0.00000000	0.00000000
Equity(12 [ADS])	0.00000000	0.00000000	0.00000000
Equity(13 [ADSK])	0.00000000	0.00000000	0.00000000
Equity(14 [AEE])	0.00000000	0.00000000	0.00000000
Equity(15 [AEP])	0.00000000	0.00000000	0.00000000
Equity(16 [AES])	0.00000000	0.00000000	0.00000000
Equity(17 [AET])	0.00000000	0.00000000	0.00000000
Equity(18 [AFL])	0.00000000	0.00000000	0.00000000
Equity(19 [AGN])	0.00000000	0.00000000	0.00000000
Equity(20 [AIG])	0.00000000	0.00000000	0.00000000
Equity(21 [AIV])	0.00000000	0.00000000	0.00000000
Equity(22 [AIZ])	0.00000000	0.00000000	0.00000000
Equity(23 [AJG])	0.00000000	0.00000000	0.00000000
Equity(24 [AKAM])	0.00000000	0.00000000	0.00000000
Equity(25 [ALB])	0.00000000	0.00000000	0.00000000
Equity(26 [ALGN])	0.00000000	0.00000000	0.00000000
Equity(27 [ALK])	0.00000000	0.00000000	0.00000000
Equity(28 [ALL])	0.00000000	0.00000000	0.00000000
Equity(29 [ALLE])	0.00000000	0.00000000	0.00000000
...	...	...	...
Equity(460 [VRSN])	0.00000000	0.00000000	0.00000000
Equity(461 [VRTX])	0.00000000	0.00000000	0.00000000
Equity(462 [VTR])	0.00000000	0.00000000	0.00000000
Equity(463 [VZ])	0.00000000	0.00000000	0.00000000
Equity(464 [WAT])	0.00000000	0.00000000	0.00000000
Equity(465 [WBA])	0.00000000	0.00000000	0.00000000
Equity(466 [WDC])	0.00000000	0.00000000	0.00000000
Equity(467 [WEC])	0.00000000	0.00000000	0.00000000
Equity(468 [WFC])	0.00000000	0.00000000	0.00000000
Equity(469 [WHR])	0.00000000	0.00000000	0.00000000
Equity(471 [WM])	0.00000000	0.00000000	0.00000000
Equity(472 [WMB])	0.00000000	0.00000000	0.00000000
Equity(473 [WMT])	0.00000000	0.00000000	0.00000000
Equity(474 [WRK])	0.00000000	0.00000000	0.00000000
Equity(475 [WU])	0.00000000	0.00000000	0.00000000
Equity(476 [WY])	0.00000000	0.00000000	0.00000000
Equity(477 [WYN])	0.00000000	0.00000000	0.00000000
Equity(478 [WYNN])	0.00000000	0.00000000	0.00000000
Equity(479 [XEC])	0.00000000	0.00000000	0.00000000
Equity(480 [XEL])	0.00000000	0.00000000	0.00000000
Equity(481 [XL])	0.00000000	0.00000000	0.00000000
Equity(482 [XLNX])	0.00000000	0.00000000	0.00000000
Equity(483 [XOM])	0.00000000	0.00000000	0.00000000
Equity(484 [XRAY])	0.00000000	0.00000000	0.00000000
Equity(485 [XRX])	0.00000000	0.00000000	0.00000000

```
Equity(486 [XYL])      0.00000000       0.00000000       0.00000000
Equity(487 [YUM])      0.00000000       0.00000000       0.00000000
Equity(488 [ZBH])      0.00000000       0.00000000       0.00000000
Equity(489 [ZION])     0.00000000       0.00000000       0.00000000
Equity(490 [ZTS])      0.00000000       0.00000000       0.00000000

                   Equity(3 [AAPL])  Equity(4 [ABBV])  Equity(5 [ABC])  \
Equity(0 [A])            0.00000000        0.00000000       0.00000000
Equity(1 [AAL])          0.00000000        0.00000000       0.00000000
Equity(2 [AAP])          0.00000000        0.00000000       0.00000000
Equity(3 [AAPL])         0.04801884        0.00000000       0.00000000
Equity(4 [ABBV])         0.00000000        0.03040361       0.00000000
Equity(5 [ABC])          0.00000000        0.00000000       0.01854504
Equity(6 [ABT])          0.00000000        0.00000000       0.00000000
Equity(7 [ACN])          0.00000000        0.00000000       0.00000000
Equity(8 [ADBE])         0.00000000        0.00000000       0.00000000
Equity(9 [ADI])          0.00000000        0.00000000       0.00000000
Equity(10 [ADM])         0.00000000        0.00000000       0.00000000
Equity(11 [ADP])         0.00000000        0.00000000       0.00000000
Equity(12 [ADS])         0.00000000        0.00000000       0.00000000
Equity(13 [ADSK])        0.00000000        0.00000000       0.00000000
Equity(14 [AEE])         0.00000000        0.00000000       0.00000000
Equity(15 [AEP])         0.00000000        0.00000000       0.00000000
Equity(16 [AES])         0.00000000        0.00000000       0.00000000
Equity(17 [AET])         0.00000000        0.00000000       0.00000000
Equity(18 [AFL])         0.00000000        0.00000000       0.00000000
Equity(19 [AGN])         0.00000000        0.00000000       0.00000000
Equity(20 [AIG])         0.00000000        0.00000000       0.00000000
Equity(21 [AIV])         0.00000000        0.00000000       0.00000000
Equity(22 [AIZ])         0.00000000        0.00000000       0.00000000
Equity(23 [AJG])         0.00000000        0.00000000       0.00000000
Equity(24 [AKAM])        0.00000000        0.00000000       0.00000000
Equity(25 [ALB])         0.00000000        0.00000000       0.00000000
Equity(26 [ALGN])        0.00000000        0.00000000       0.00000000
Equity(27 [ALK])         0.00000000        0.00000000       0.00000000
Equity(28 [ALL])         0.00000000        0.00000000       0.00000000
Equity(29 [ALLE])        0.00000000        0.00000000       0.00000000
...                             ...               ...              ...
Equity(460 [VRSN])       0.00000000        0.00000000       0.00000000
Equity(461 [VRTX])       0.00000000        0.00000000       0.00000000
Equity(462 [VTR])        0.00000000        0.00000000       0.00000000
Equity(463 [VZ])         0.00000000        0.00000000       0.00000000
Equity(464 [WAT])        0.00000000        0.00000000       0.00000000
Equity(465 [WBA])        0.00000000        0.00000000       0.00000000
Equity(466 [WDC])        0.00000000        0.00000000       0.00000000
Equity(467 [WEC])        0.00000000        0.00000000       0.00000000
Equity(468 [WFC])        0.00000000        0.00000000       0.00000000
Equity(469 [WHR])        0.00000000        0.00000000       0.00000000
```

Equity(471 [WM])	0.00000000	0.00000000	0.00000000
Equity(472 [WMB])	0.00000000	0.00000000	0.00000000
Equity(473 [WMT])	0.00000000	0.00000000	0.00000000
Equity(474 [WRK])	0.00000000	0.00000000	0.00000000
Equity(475 [WU])	0.00000000	0.00000000	0.00000000
Equity(476 [WY])	0.00000000	0.00000000	0.00000000
Equity(477 [WYN])	0.00000000	0.00000000	0.00000000
Equity(478 [WYNN])	0.00000000	0.00000000	0.00000000
Equity(479 [XEC])	0.00000000	0.00000000	0.00000000
Equity(480 [XEL])	0.00000000	0.00000000	0.00000000
Equity(481 [XL])	0.00000000	0.00000000	0.00000000
Equity(482 [XLNX])	0.00000000	0.00000000	0.00000000
Equity(483 [XOM])	0.00000000	0.00000000	0.00000000
Equity(484 [XRAY])	0.00000000	0.00000000	0.00000000
Equity(485 [XRX])	0.00000000	0.00000000	0.00000000
Equity(486 [XYL])	0.00000000	0.00000000	0.00000000
Equity(487 [YUM])	0.00000000	0.00000000	0.00000000
Equity(488 [ZBH])	0.00000000	0.00000000	0.00000000
Equity(489 [ZION])	0.00000000	0.00000000	0.00000000
Equity(490 [ZTS])	0.00000000	0.00000000	0.00000000

	Equity(6 [ABT])	Equity(7 [ACN])	Equity(8 [ADBE])	\
Equity(0 [A])	0.00000000	0.00000000	0.00000000	
Equity(1 [AAL])	0.00000000	0.00000000	0.00000000	
Equity(2 [AAP])	0.00000000	0.00000000	0.00000000	
Equity(3 [AAPL])	0.00000000	0.00000000	0.00000000	
Equity(4 [ABBV])	0.00000000	0.00000000	0.00000000	
Equity(5 [ABC])	0.00000000	0.00000000	0.00000000	
Equity(6 [ABT])	0.01481514	0.00000000	0.00000000	
Equity(7 [ACN])	0.00000000	0.02177470	0.00000000	
Equity(8 [ADBE])	0.00000000	0.00000000	0.03442125	
Equity(9 [ADI])	0.00000000	0.00000000	0.00000000	
Equity(10 [ADM])	0.00000000	0.00000000	0.00000000	
Equity(11 [ADP])	0.00000000	0.00000000	0.00000000	
Equity(12 [ADS])	0.00000000	0.00000000	0.00000000	
Equity(13 [ADSK])	0.00000000	0.00000000	0.00000000	
Equity(14 [AEE])	0.00000000	0.00000000	0.00000000	
Equity(15 [AEP])	0.00000000	0.00000000	0.00000000	
Equity(16 [AES])	0.00000000	0.00000000	0.00000000	
Equity(17 [AET])	0.00000000	0.00000000	0.00000000	
Equity(18 [AFL])	0.00000000	0.00000000	0.00000000	
Equity(19 [AGN])	0.00000000	0.00000000	0.00000000	
Equity(20 [AIG])	0.00000000	0.00000000	0.00000000	
Equity(21 [AIV])	0.00000000	0.00000000	0.00000000	
Equity(22 [AIZ])	0.00000000	0.00000000	0.00000000	
Equity(23 [AJG])	0.00000000	0.00000000	0.00000000	
Equity(24 [AKAM])	0.00000000	0.00000000	0.00000000	
Equity(25 [ALB])	0.00000000	0.00000000	0.00000000	

```
Equity(26 [ALGN])        0.00000000       0.00000000        0.00000000
Equity(27 [ALK])         0.00000000       0.00000000        0.00000000
Equity(28 [ALL])         0.00000000       0.00000000        0.00000000
Equity(29 [ALLE])        0.00000000       0.00000000        0.00000000
...                             ...              ...               ...
Equity(460 [VRSN])       0.00000000       0.00000000        0.00000000
Equity(461 [VRTX])       0.00000000       0.00000000        0.00000000
Equity(462 [VTR])        0.00000000       0.00000000        0.00000000
Equity(463 [VZ])         0.00000000       0.00000000        0.00000000
Equity(464 [WAT])        0.00000000       0.00000000        0.00000000
Equity(465 [WBA])        0.00000000       0.00000000        0.00000000
Equity(466 [WDC])        0.00000000       0.00000000        0.00000000
Equity(467 [WEC])        0.00000000       0.00000000        0.00000000
Equity(468 [WFC])        0.00000000       0.00000000        0.00000000
Equity(469 [WHR])        0.00000000       0.00000000        0.00000000
Equity(471 [WM])         0.00000000       0.00000000        0.00000000
Equity(472 [WMB])        0.00000000       0.00000000        0.00000000
Equity(473 [WMT])        0.00000000       0.00000000        0.00000000
Equity(474 [WRK])        0.00000000       0.00000000        0.00000000
Equity(475 [WU])         0.00000000       0.00000000        0.00000000
Equity(476 [WY])         0.00000000       0.00000000        0.00000000
Equity(477 [WYN])        0.00000000       0.00000000        0.00000000
Equity(478 [WYNN])       0.00000000       0.00000000        0.00000000
Equity(479 [XEC])        0.00000000       0.00000000        0.00000000
Equity(480 [XEL])        0.00000000       0.00000000        0.00000000
Equity(481 [XL])         0.00000000       0.00000000        0.00000000
Equity(482 [XLNX])       0.00000000       0.00000000        0.00000000
Equity(483 [XOM])        0.00000000       0.00000000        0.00000000
Equity(484 [XRAY])       0.00000000       0.00000000        0.00000000
Equity(485 [XRX])        0.00000000       0.00000000        0.00000000
Equity(486 [XYL])        0.00000000       0.00000000        0.00000000
Equity(487 [YUM])        0.00000000       0.00000000        0.00000000
Equity(488 [ZBH])        0.00000000       0.00000000        0.00000000
Equity(489 [ZION])       0.00000000       0.00000000        0.00000000
Equity(490 [ZTS])        0.00000000       0.00000000        0.00000000

                   Equity(9 [ADI])        ...          Equity(481 [XL])  \
Equity(0 [A])            0.00000000       ...                0.00000000
Equity(1 [AAL])          0.00000000       ...                0.00000000
Equity(2 [AAP])          0.00000000       ...                0.00000000
Equity(3 [AAPL])         0.00000000       ...                0.00000000
Equity(4 [ABBV])         0.00000000       ...                0.00000000
Equity(5 [ABC])          0.00000000       ...                0.00000000
Equity(6 [ABT])          0.00000000       ...                0.00000000
Equity(7 [ACN])          0.00000000       ...                0.00000000
Equity(8 [ADBE])         0.00000000       ...                0.00000000
Equity(9 [ADI])          0.01898404       ...                0.00000000
Equity(10 [ADM])         0.00000000       ...                0.00000000
```

```
Equity(11 [ADP])        0.00000000        ...                0.00000000
Equity(12 [ADS])        0.00000000        ...                0.00000000
Equity(13 [ADSK])       0.00000000        ...                0.00000000
Equity(14 [AEE])        0.00000000        ...                0.00000000
Equity(15 [AEP])        0.00000000        ...                0.00000000
Equity(16 [AES])        0.00000000        ...                0.00000000
Equity(17 [AET])        0.00000000        ...                0.00000000
Equity(18 [AFL])        0.00000000        ...                0.00000000
Equity(19 [AGN])        0.00000000        ...                0.00000000
Equity(20 [AIG])        0.00000000        ...                0.00000000
Equity(21 [AIV])        0.00000000        ...                0.00000000
Equity(22 [AIZ])        0.00000000        ...                0.00000000
Equity(23 [AJG])        0.00000000        ...                0.00000000
Equity(24 [AKAM])       0.00000000        ...                0.00000000
Equity(25 [ALB])        0.00000000        ...                0.00000000
Equity(26 [ALGN])       0.00000000        ...                0.00000000
Equity(27 [ALK])        0.00000000        ...                0.00000000
Equity(28 [ALL])        0.00000000        ...                0.00000000
Equity(29 [ALLE])       0.00000000        ...                0.00000000
...                           ...         ...                       ...
Equity(460 [VRSN])      0.00000000        ...                0.00000000
Equity(461 [VRTX])      0.00000000        ...                0.00000000
Equity(462 [VTR])       0.00000000        ...                0.00000000
Equity(463 [VZ])        0.00000000        ...                0.00000000
Equity(464 [WAT])       0.00000000        ...                0.00000000
Equity(465 [WBA])       0.00000000        ...                0.00000000
Equity(466 [WDC])       0.00000000        ...                0.00000000
Equity(467 [WEC])       0.00000000        ...                0.00000000
Equity(468 [WFC])       0.00000000        ...                0.00000000
Equity(469 [WHR])       0.00000000        ...                0.00000000
Equity(471 [WM])        0.00000000        ...                0.00000000
Equity(472 [WMB])       0.00000000        ...                0.00000000
Equity(473 [WMT])       0.00000000        ...                0.00000000
Equity(474 [WRK])       0.00000000        ...                0.00000000
Equity(475 [WU])        0.00000000        ...                0.00000000
Equity(476 [WY])        0.00000000        ...                0.00000000
Equity(477 [WYN])       0.00000000        ...                0.00000000
Equity(478 [WYNN])      0.00000000        ...                0.00000000
Equity(479 [XEC])       0.00000000        ...                0.00000000
Equity(480 [XEL])       0.00000000        ...                0.00000000
Equity(481 [XL])        0.00000000        ...                0.02051926
Equity(482 [XLNX])      0.00000000        ...                0.00000000
Equity(483 [XOM])       0.00000000        ...                0.00000000
Equity(484 [XRAY])      0.00000000        ...                0.00000000
Equity(485 [XRX])       0.00000000        ...                0.00000000
Equity(486 [XYL])       0.00000000        ...                0.00000000
Equity(487 [YUM])       0.00000000        ...                0.00000000
Equity(488 [ZBH])       0.00000000        ...                0.00000000
```

```
Equity(489 [ZION])       0.00000000        ...                0.00000000
Equity(490 [ZTS])        0.00000000        ...                0.00000000

                   Equity(482 [XLNX])  Equity(483 [XOM])  Equity(484 [XRAY])  \
Equity(0 [A])              0.00000000         0.00000000          0.00000000
Equity(1 [AAL])            0.00000000         0.00000000          0.00000000
Equity(2 [AAP])            0.00000000         0.00000000          0.00000000
Equity(3 [AAPL])           0.00000000         0.00000000          0.00000000
Equity(4 [ABBV])           0.00000000         0.00000000          0.00000000
Equity(5 [ABC])            0.00000000         0.00000000          0.00000000
Equity(6 [ABT])            0.00000000         0.00000000          0.00000000
Equity(7 [ACN])            0.00000000         0.00000000          0.00000000
Equity(8 [ADBE])           0.00000000         0.00000000          0.00000000
Equity(9 [ADI])            0.00000000         0.00000000          0.00000000
Equity(10 [ADM])           0.00000000         0.00000000          0.00000000
Equity(11 [ADP])           0.00000000         0.00000000          0.00000000
Equity(12 [ADS])           0.00000000         0.00000000          0.00000000
Equity(13 [ADSK])          0.00000000         0.00000000          0.00000000
Equity(14 [AEE])           0.00000000         0.00000000          0.00000000
Equity(15 [AEP])           0.00000000         0.00000000          0.00000000
Equity(16 [AES])           0.00000000         0.00000000          0.00000000
Equity(17 [AET])           0.00000000         0.00000000          0.00000000
Equity(18 [AFL])           0.00000000         0.00000000          0.00000000
Equity(19 [AGN])           0.00000000         0.00000000          0.00000000
Equity(20 [AIG])           0.00000000         0.00000000          0.00000000
Equity(21 [AIV])           0.00000000         0.00000000          0.00000000
Equity(22 [AIZ])           0.00000000         0.00000000          0.00000000
Equity(23 [AJG])           0.00000000         0.00000000          0.00000000
Equity(24 [AKAM])          0.00000000         0.00000000          0.00000000
Equity(25 [ALB])           0.00000000         0.00000000          0.00000000
Equity(26 [ALGN])          0.00000000         0.00000000          0.00000000
Equity(27 [ALK])           0.00000000         0.00000000          0.00000000
Equity(28 [ALL])           0.00000000         0.00000000          0.00000000
Equity(29 [ALLE])          0.00000000         0.00000000          0.00000000
...                               ...                ...                 ...
Equity(460 [VRSN])         0.00000000         0.00000000          0.00000000
Equity(461 [VRTX])         0.00000000         0.00000000          0.00000000
Equity(462 [VTR])          0.00000000         0.00000000          0.00000000
Equity(463 [VZ])           0.00000000         0.00000000          0.00000000
Equity(464 [WAT])          0.00000000         0.00000000          0.00000000
Equity(465 [WBA])          0.00000000         0.00000000          0.00000000
Equity(466 [WDC])          0.00000000         0.00000000          0.00000000
Equity(467 [WEC])          0.00000000         0.00000000          0.00000000
Equity(468 [WFC])          0.00000000         0.00000000          0.00000000
Equity(469 [WHR])          0.00000000         0.00000000          0.00000000
Equity(471 [WM])           0.00000000         0.00000000          0.00000000
Equity(472 [WMB])          0.00000000         0.00000000          0.00000000
Equity(473 [WMT])          0.00000000         0.00000000          0.00000000
```

Equity(474 [WRK])	0.00000000	0.00000000	0.00000000
Equity(475 [WU])	0.00000000	0.00000000	0.00000000
Equity(476 [WY])	0.00000000	0.00000000	0.00000000
Equity(477 [WYN])	0.00000000	0.00000000	0.00000000
Equity(478 [WYNN])	0.00000000	0.00000000	0.00000000
Equity(479 [XEC])	0.00000000	0.00000000	0.00000000
Equity(480 [XEL])	0.00000000	0.00000000	0.00000000
Equity(481 [XL])	0.00000000	0.00000000	0.00000000
Equity(482 [XLNX])	0.02684299	0.00000000	0.00000000
Equity(483 [XOM])	0.00000000	0.01059841	0.00000000
Equity(484 [XRAY])	0.00000000	0.00000000	0.01537171
Equity(485 [XRX])	0.00000000	0.00000000	0.00000000
Equity(486 [XYL])	0.00000000	0.00000000	0.00000000
Equity(487 [YUM])	0.00000000	0.00000000	0.00000000
Equity(488 [ZBH])	0.00000000	0.00000000	0.00000000
Equity(489 [ZION])	0.00000000	0.00000000	0.00000000
Equity(490 [ZTS])	0.00000000	0.00000000	0.00000000

	Equity(485 [XRX])	Equity(486 [XYL])	Equity(487 [YUM])	\
Equity(0 [A])	0.00000000	0.00000000	0.00000000	
Equity(1 [AAL])	0.00000000	0.00000000	0.00000000	
Equity(2 [AAP])	0.00000000	0.00000000	0.00000000	
Equity(3 [AAPL])	0.00000000	0.00000000	0.00000000	
Equity(4 [ABBV])	0.00000000	0.00000000	0.00000000	
Equity(5 [ABC])	0.00000000	0.00000000	0.00000000	
Equity(6 [ABT])	0.00000000	0.00000000	0.00000000	
Equity(7 [ACN])	0.00000000	0.00000000	0.00000000	
Equity(8 [ADBE])	0.00000000	0.00000000	0.00000000	
Equity(9 [ADI])	0.00000000	0.00000000	0.00000000	
Equity(10 [ADM])	0.00000000	0.00000000	0.00000000	
Equity(11 [ADP])	0.00000000	0.00000000	0.00000000	
Equity(12 [ADS])	0.00000000	0.00000000	0.00000000	
Equity(13 [ADSK])	0.00000000	0.00000000	0.00000000	
Equity(14 [AEE])	0.00000000	0.00000000	0.00000000	
Equity(15 [AEP])	0.00000000	0.00000000	0.00000000	
Equity(16 [AES])	0.00000000	0.00000000	0.00000000	
Equity(17 [AET])	0.00000000	0.00000000	0.00000000	
Equity(18 [AFL])	0.00000000	0.00000000	0.00000000	
Equity(19 [AGN])	0.00000000	0.00000000	0.00000000	
Equity(20 [AIG])	0.00000000	0.00000000	0.00000000	
Equity(21 [AIV])	0.00000000	0.00000000	0.00000000	
Equity(22 [AIZ])	0.00000000	0.00000000	0.00000000	
Equity(23 [AJG])	0.00000000	0.00000000	0.00000000	
Equity(24 [AKAM])	0.00000000	0.00000000	0.00000000	
Equity(25 [ALB])	0.00000000	0.00000000	0.00000000	
Equity(26 [ALGN])	0.00000000	0.00000000	0.00000000	
Equity(27 [ALK])	0.00000000	0.00000000	0.00000000	
Equity(28 [ALL])	0.00000000	0.00000000	0.00000000	

Equity(29 [ALLE])	0.00000000	0.00000000	0.00000000
...	...	...	...
Equity(460 [VRSN])	0.00000000	0.00000000	0.00000000
Equity(461 [VRTX])	0.00000000	0.00000000	0.00000000
Equity(462 [VTR])	0.00000000	0.00000000	0.00000000
Equity(463 [VZ])	0.00000000	0.00000000	0.00000000
Equity(464 [WAT])	0.00000000	0.00000000	0.00000000
Equity(465 [WBA])	0.00000000	0.00000000	0.00000000
Equity(466 [WDC])	0.00000000	0.00000000	0.00000000
Equity(467 [WEC])	0.00000000	0.00000000	0.00000000
Equity(468 [WFC])	0.00000000	0.00000000	0.00000000
Equity(469 [WHR])	0.00000000	0.00000000	0.00000000
Equity(471 [WM])	0.00000000	0.00000000	0.00000000
Equity(472 [WMB])	0.00000000	0.00000000	0.00000000
Equity(473 [WMT])	0.00000000	0.00000000	0.00000000
Equity(474 [WRK])	0.00000000	0.00000000	0.00000000
Equity(475 [WU])	0.00000000	0.00000000	0.00000000
Equity(476 [WY])	0.00000000	0.00000000	0.00000000
Equity(477 [WYN])	0.00000000	0.00000000	0.00000000
Equity(478 [WYNN])	0.00000000	0.00000000	0.00000000
Equity(479 [XEC])	0.00000000	0.00000000	0.00000000
Equity(480 [XEL])	0.00000000	0.00000000	0.00000000
Equity(481 [XL])	0.00000000	0.00000000	0.00000000
Equity(482 [XLNX])	0.00000000	0.00000000	0.00000000
Equity(483 [XOM])	0.00000000	0.00000000	0.00000000
Equity(484 [XRAY])	0.00000000	0.00000000	0.00000000
Equity(485 [XRX])	0.03946866	0.00000000	0.00000000
Equity(486 [XYL])	0.00000000	0.03191603	0.00000000
Equity(487 [YUM])	0.00000000	0.00000000	0.04385518
Equity(488 [ZBH])	0.00000000	0.00000000	0.00000000
Equity(489 [ZION])	0.00000000	0.00000000	0.00000000
Equity(490 [ZTS])	0.00000000	0.00000000	0.00000000

	Equity(488 [ZBH])	Equity(489 [ZION])	Equity(490 [ZTS])
Equity(0 [A])	0.00000000	0.00000000	0.00000000
Equity(1 [AAL])	0.00000000	0.00000000	0.00000000
Equity(2 [AAP])	0.00000000	0.00000000	0.00000000
Equity(3 [AAPL])	0.00000000	0.00000000	0.00000000
Equity(4 [ABBV])	0.00000000	0.00000000	0.00000000
Equity(5 [ABC])	0.00000000	0.00000000	0.00000000
Equity(6 [ABT])	0.00000000	0.00000000	0.00000000
Equity(7 [ACN])	0.00000000	0.00000000	0.00000000
Equity(8 [ADBE])	0.00000000	0.00000000	0.00000000
Equity(9 [ADI])	0.00000000	0.00000000	0.00000000
Equity(10 [ADM])	0.00000000	0.00000000	0.00000000
Equity(11 [ADP])	0.00000000	0.00000000	0.00000000
Equity(12 [ADS])	0.00000000	0.00000000	0.00000000
Equity(13 [ADSK])	0.00000000	0.00000000	0.00000000

Equity(14 [AEE])	0.00000000	0.00000000	0.00000000
Equity(15 [AEP])	0.00000000	0.00000000	0.00000000
Equity(16 [AES])	0.00000000	0.00000000	0.00000000
Equity(17 [AET])	0.00000000	0.00000000	0.00000000
Equity(18 [AFL])	0.00000000	0.00000000	0.00000000
Equity(19 [AGN])	0.00000000	0.00000000	0.00000000
Equity(20 [AIG])	0.00000000	0.00000000	0.00000000
Equity(21 [AIV])	0.00000000	0.00000000	0.00000000
Equity(22 [AIZ])	0.00000000	0.00000000	0.00000000
Equity(23 [AJG])	0.00000000	0.00000000	0.00000000
Equity(24 [AKAM])	0.00000000	0.00000000	0.00000000
Equity(25 [ALB])	0.00000000	0.00000000	0.00000000
Equity(26 [ALGN])	0.00000000	0.00000000	0.00000000
Equity(27 [ALK])	0.00000000	0.00000000	0.00000000
Equity(28 [ALL])	0.00000000	0.00000000	0.00000000
Equity(29 [ALLE])	0.00000000	0.00000000	0.00000000
...	...	...	...
Equity(460 [VRSN])	0.00000000	0.00000000	0.00000000
Equity(461 [VRTX])	0.00000000	0.00000000	0.00000000
Equity(462 [VTR])	0.00000000	0.00000000	0.00000000
Equity(463 [VZ])	0.00000000	0.00000000	0.00000000
Equity(464 [WAT])	0.00000000	0.00000000	0.00000000
Equity(465 [WBA])	0.00000000	0.00000000	0.00000000
Equity(466 [WDC])	0.00000000	0.00000000	0.00000000
Equity(467 [WEC])	0.00000000	0.00000000	0.00000000
Equity(468 [WFC])	0.00000000	0.00000000	0.00000000
Equity(469 [WHR])	0.00000000	0.00000000	0.00000000
Equity(471 [WM])	0.00000000	0.00000000	0.00000000
Equity(472 [WMB])	0.00000000	0.00000000	0.00000000
Equity(473 [WMT])	0.00000000	0.00000000	0.00000000
Equity(474 [WRK])	0.00000000	0.00000000	0.00000000
Equity(475 [WU])	0.00000000	0.00000000	0.00000000
Equity(476 [WY])	0.00000000	0.00000000	0.00000000
Equity(477 [WYN])	0.00000000	0.00000000	0.00000000
Equity(478 [WYNN])	0.00000000	0.00000000	0.00000000
Equity(479 [XEC])	0.00000000	0.00000000	0.00000000
Equity(480 [XEL])	0.00000000	0.00000000	0.00000000
Equity(481 [XL])	0.00000000	0.00000000	0.00000000
Equity(482 [XLNX])	0.00000000	0.00000000	0.00000000
Equity(483 [XOM])	0.00000000	0.00000000	0.00000000
Equity(484 [XRAY])	0.00000000	0.00000000	0.00000000
Equity(485 [XRX])	0.00000000	0.00000000	0.00000000
Equity(486 [XYL])	0.00000000	0.00000000	0.00000000
Equity(487 [YUM])	0.00000000	0.00000000	0.00000000
Equity(488 [ZBH])	0.02233019	0.00000000	0.00000000
Equity(489 [ZION])	0.00000000	0.02337210	0.00000000
Equity(490 [ZTS])	0.00000000	0.00000000	0.02735075

```
[490 rows x 490 columns]
```

2.5 Idiosyncratic Variance Vector

Implement `idiosyncratic_var_vector` to get the idiosyncratic variance Vector.

```
In [20]: def idiosyncratic_var_vector(returns, idiosyncratic_var_matrix):
             """
             Get the idiosyncratic variance vector

             Parameters
             ----------
             returns : DataFrame
                 Returns for each ticker and date
             idiosyncratic_var_matrix : DataFrame
                 Idiosyncratic variance matrix

             Returns
             -------
             idiosyncratic_var_vector : DataFrame
                 Idiosyncratic variance Vector
             """

             #TODO: Implement function

             # My reasoning.
             # - I believe the diagonal of the idiosyncratic variance matrix is the variance vec
             # - The return format is a DataFrame, using np.diag() to get the diagonal vector fr
             #   return type ndarray
             # - To convert to pandas DataFrame, used the columns of the returns input argument
             #   for the new pandas DataFrame created from the diagonal vector ndarray.
             df_idiosyncratic_var_vector = pd.DataFrame( np.diag( idiosyncratic_var_matrix ),
                                                         returns.columns )

         #     # DEBUG
         #     #
         #     print( 'DEBUG - returns: {}'.format( returns ))
         #     print( 'DEBUG - idiosyncratic_var_matrix: {}'.format( idiosyncratic_var_matrix ))
         #     print( 'DEBUG - df_idiosyncratic_var_vector: {}'.format( df_idiosyncratic_var_vec
         #     print( 'DEBUG - type(df_idiosyncratic_var_vector): {}'.format( type(df_idiosyncra


             return df_idiosyncratic_var_vector


         project_tests.test_idiosyncratic_var_vector(idiosyncratic_var_vector)
```

```
Tests Passed
```

2.5.1 View Data

```
In [21]: risk_model['idiosyncratic_var_vector'] = idiosyncratic_var_vector(five_year_returns, ri

         risk_model['idiosyncratic_var_vector']
```

Out[21]:

	0
Equity(0 [A])	0.02272535
Equity(1 [AAL])	0.05190083
Equity(2 [AAP])	0.05431181
Equity(3 [AAPL])	0.04801884
Equity(4 [ABBV])	0.03040361
Equity(5 [ABC])	0.01854504
Equity(6 [ABT])	0.01481514
Equity(7 [ACN])	0.02177470
Equity(8 [ADBE])	0.03442125
Equity(9 [ADI])	0.01898404
Equity(10 [ADM])	0.02951444
Equity(11 [ADP])	0.00828126
Equity(12 [ADS])	0.02703428
Equity(13 [ADSK])	0.05224263
Equity(14 [AEE])	0.00961462
Equity(15 [AEP])	0.00800376
Equity(16 [AES])	0.03079578
Equity(17 [AET])	0.03579077
Equity(18 [AFL])	0.01894194
Equity(19 [AGN])	0.04211602
Equity(20 [AIG])	0.03317545
Equity(21 [AIV])	0.01468534
Equity(22 [AIZ])	0.02061951
Equity(23 [AJG])	0.01157320
Equity(24 [AKAM])	0.09690009
Equity(25 [ALB])	0.04106647
Equity(26 [ALGN])	0.10508661
Equity(27 [ALK])	0.03388559
Equity(28 [ALL])	0.01674196
Equity(29 [ALLE])	0.01456581
...	...
Equity(460 [VRSN])	0.04356330
Equity(461 [VRTX])	0.01133104
Equity(462 [VTR])	0.01239277
Equity(463 [VZ])	0.01826124
Equity(464 [WAT])	0.02519289
Equity(465 [WBA])	0.04833797
Equity(466 [WDC])	0.04271307
Equity(467 [WEC])	0.00660139
Equity(468 [WFC])	0.01138111
Equity(469 [WHR])	0.05778786
Equity(471 [WM])	0.01511105